

3D Processing

At the end of this Session, you will be able to:

- **Be able to calculate CMP intervals**
- **Be able to describe & calculate near & far offsets**
- **Be able to calculate nominal fold**
- **Describe the effect that decimation or summation of traces has on geometry calculations**
- **Describe how the presence of cable feathering during marine acquisition can, if unaccounted for, be detrimental to processed seismic data quality.**
- **Be able to calculate the number of sub surface tracks for 1 sailline & nominally the number in a survey.**
- **Define the term 'bin' as used in processing.**
- **Define the term 'inline (row)' as used in processing.**
- **Define the term 'crossline (column)' as used in processing.**

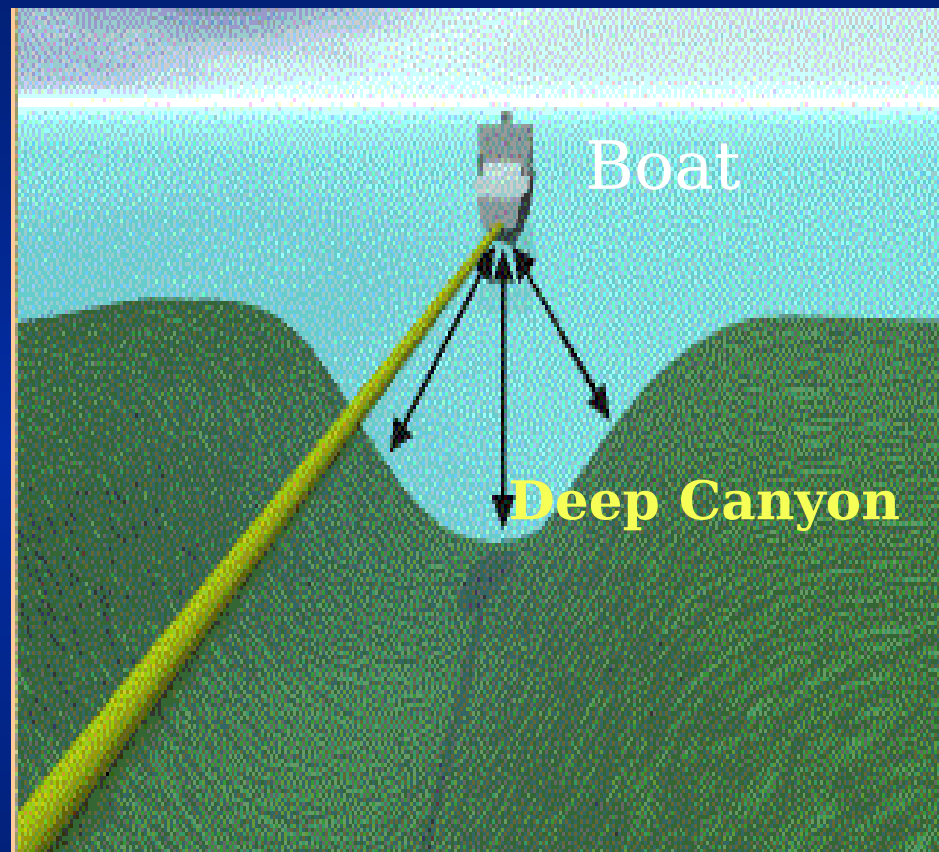
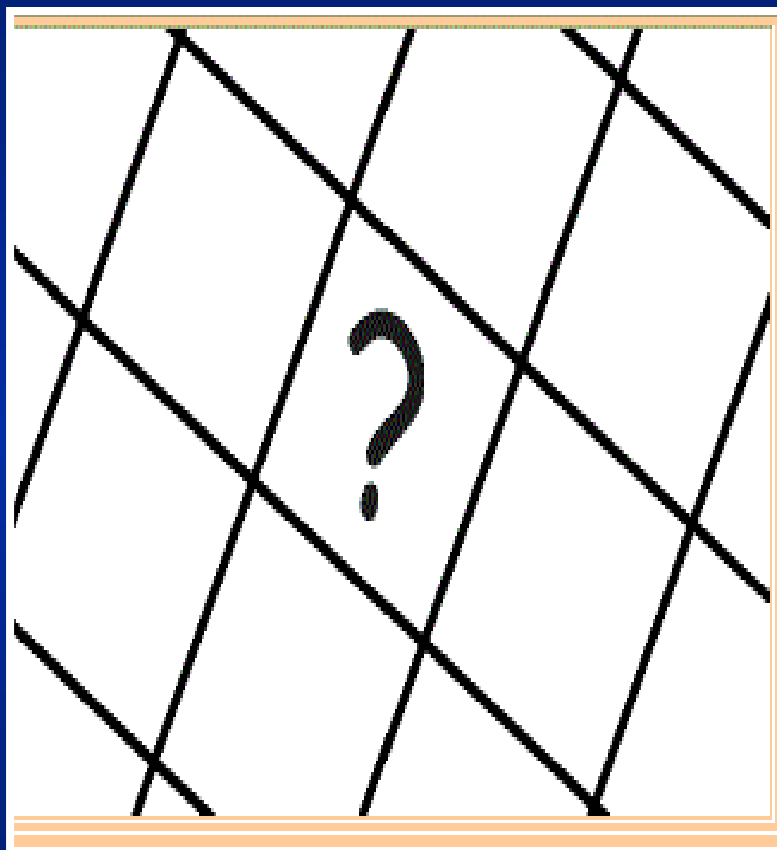
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- **Describe the Omega Master Grid**
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- **Define the term 'binning' as used in processing.**
- **Define the term 'nominal fold' as used in binning.**
- **Define the term 'maximum fold' as used in binning.**
- **Define the term 'conventional binning' as used in processing.**
- **Define the term 'flex binning' as used in processing.**
- **List the displays used to QC 3D stacking**
- **Define the term 'coverage plot (aerial map)' as used during binning.**

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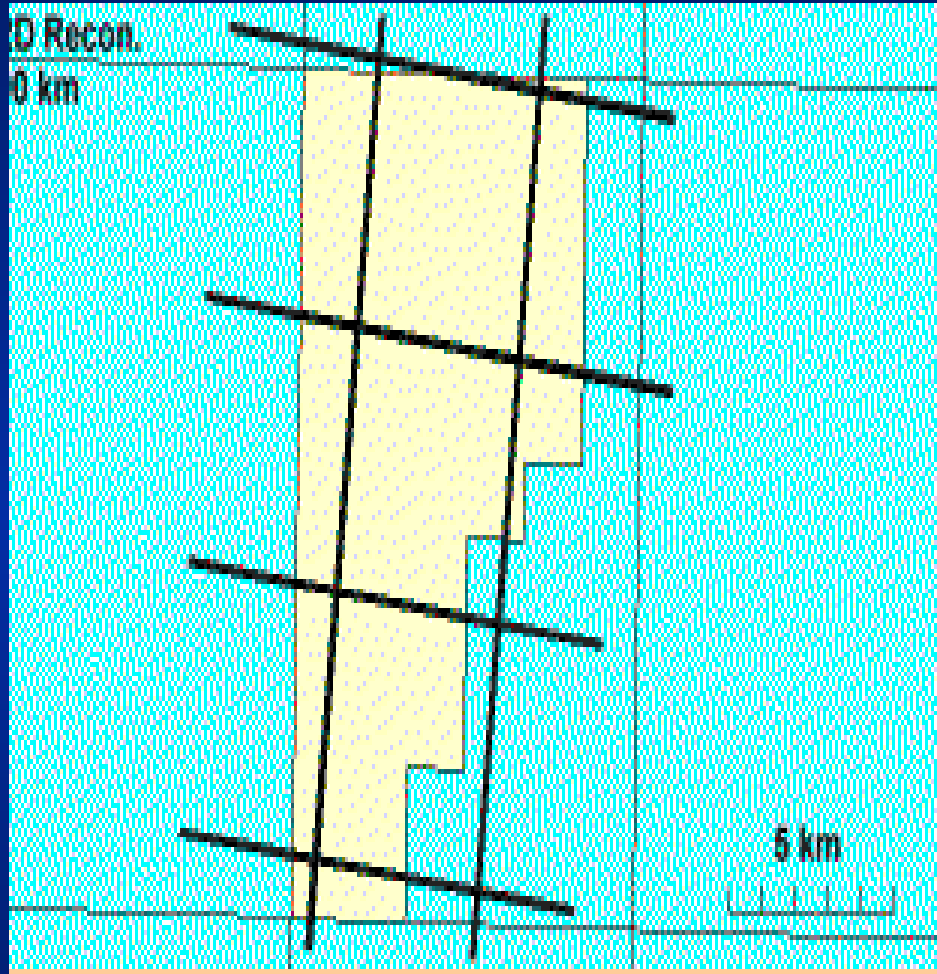
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- **Quality Control of 3D Binning**

Why 3D ?

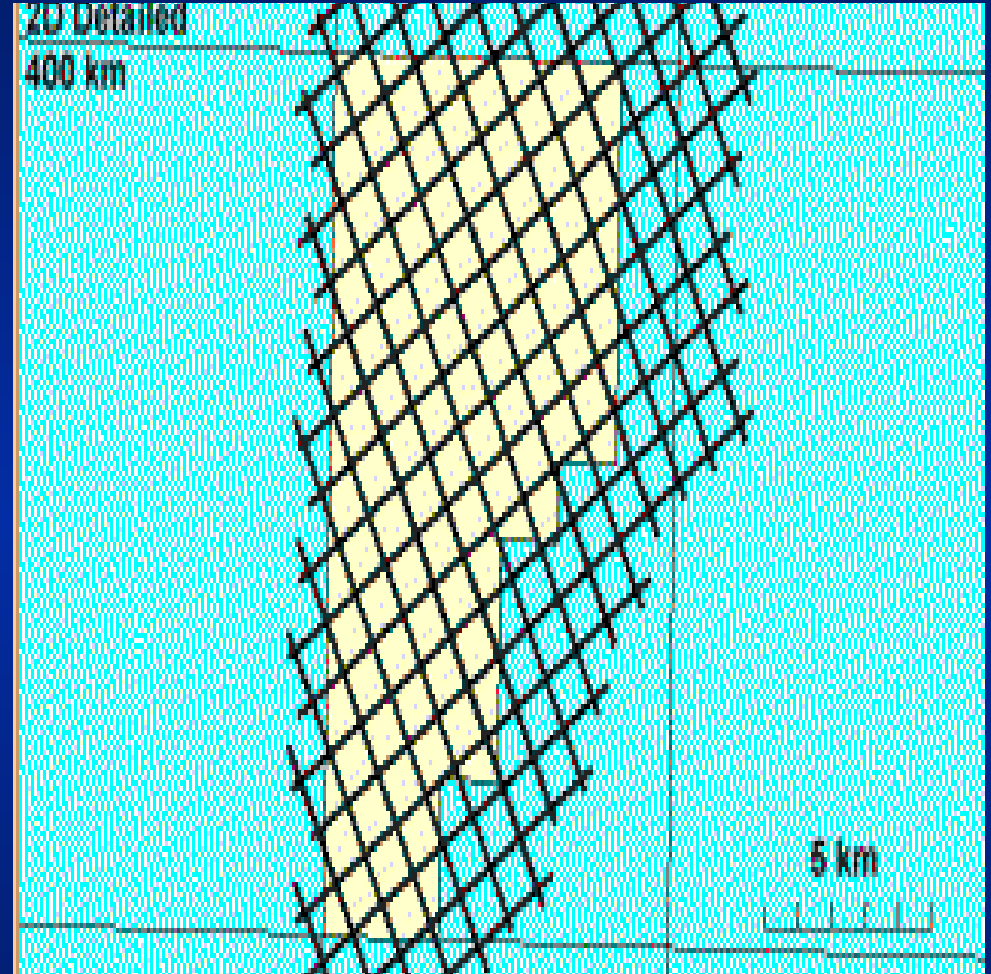


Coarse 2D Grid Three reflections from same structure

2D Surveys

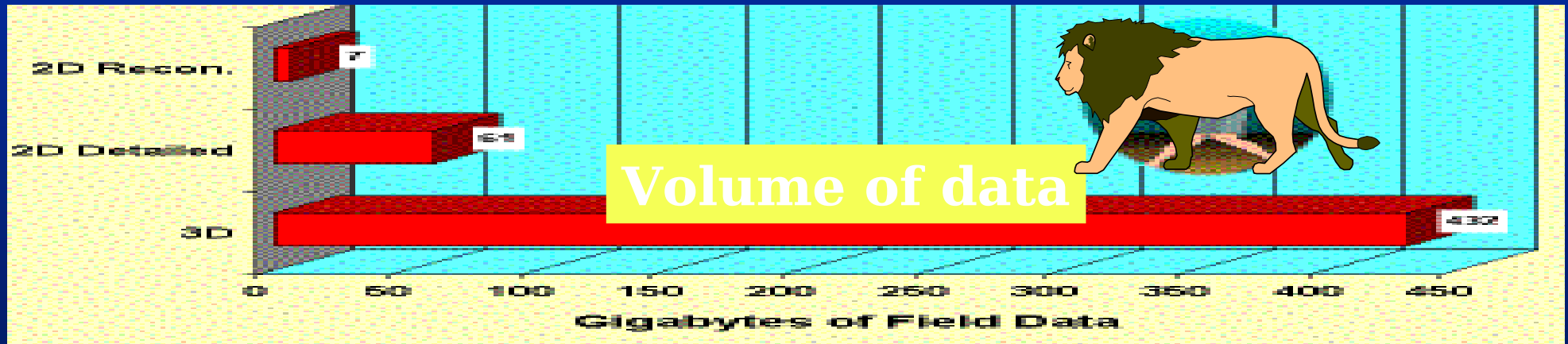
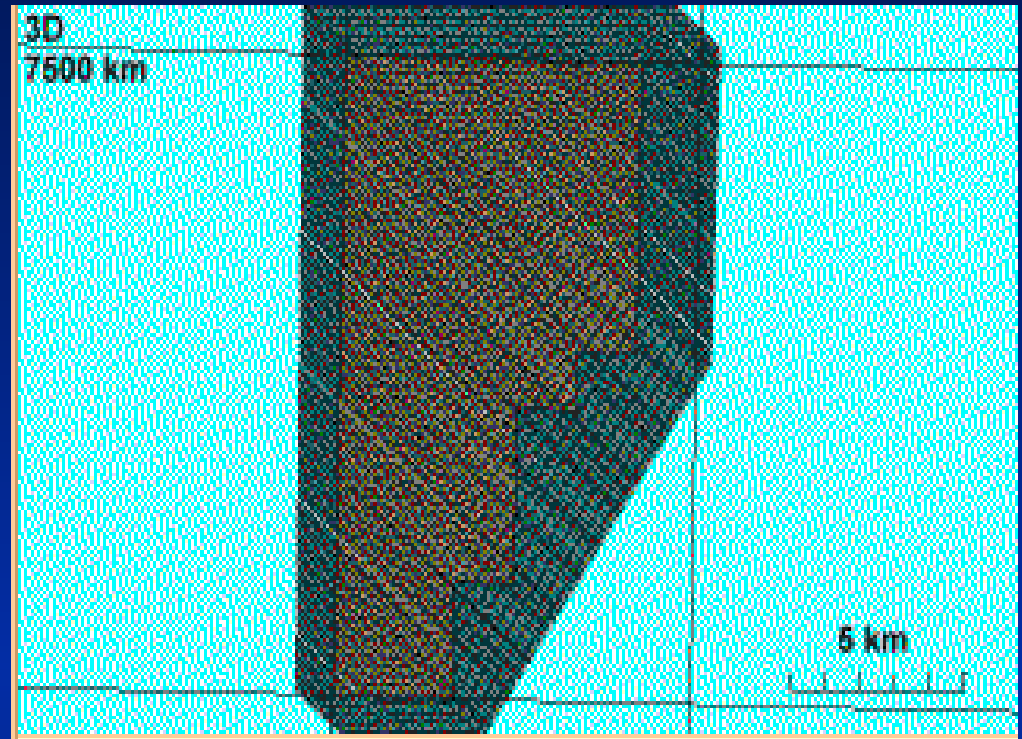


2D Reconnaissance Survey



2D Detailed Survey

A 3D Survey Grid



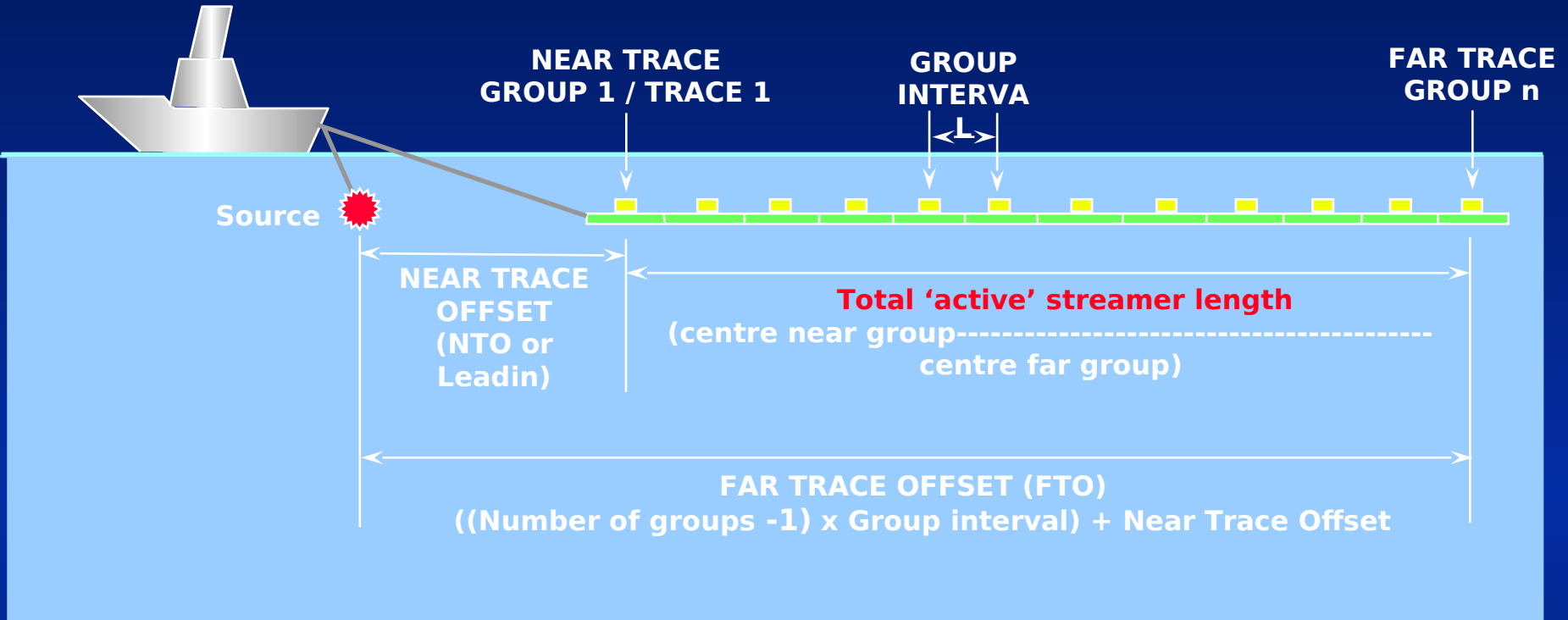
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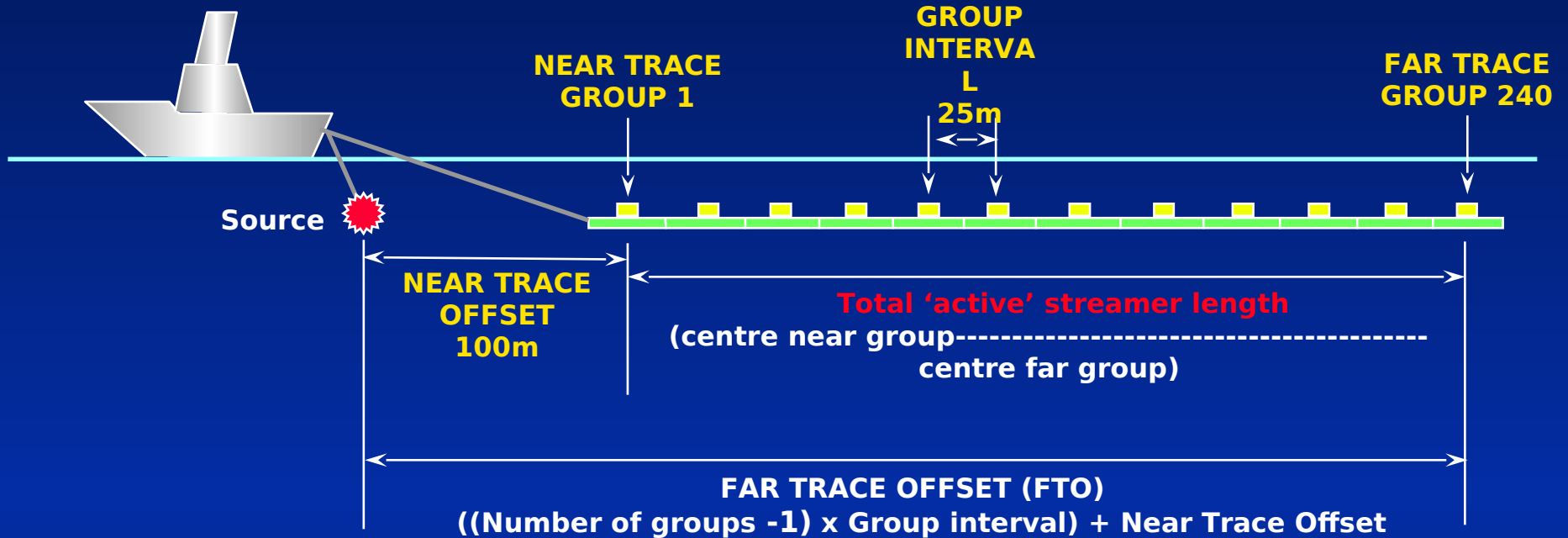
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Definitions



- **[TRACE/GROUP] OFFSET** refers to distances relative to center of source
- **OFFSETS of TRACES/GROUPS** measured to the center of streamer sections
- **OFFSETS** important measurement derived from field geometry from a **DP** perspective

Calculations



- Given the above diagram calculate the following
 - Total Active Streamer length
 - Far Trace Offset

More Calculations

For Marine acquisition parameters :

Near trace offset

310m

Group interval

50m

Calculate the following :

Number of groups

1) Total active length of streamer

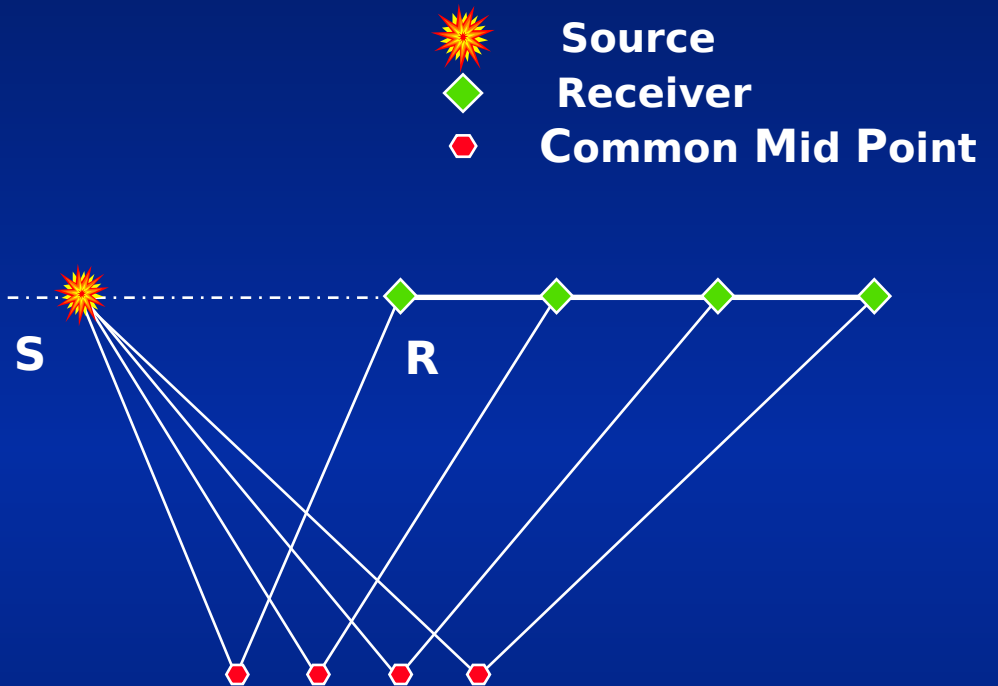
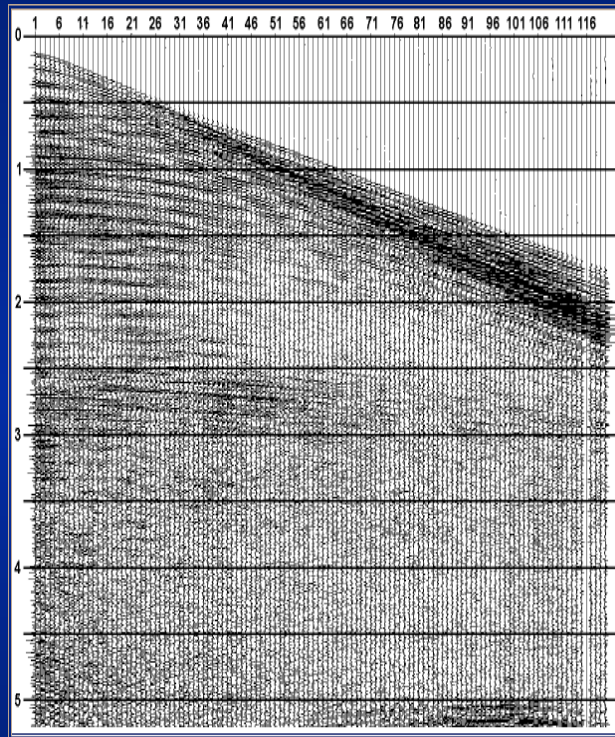
2) Offset to far receiver group

3) Offset to receiver group number 78

4) Offset of CMP for receiver group number 60

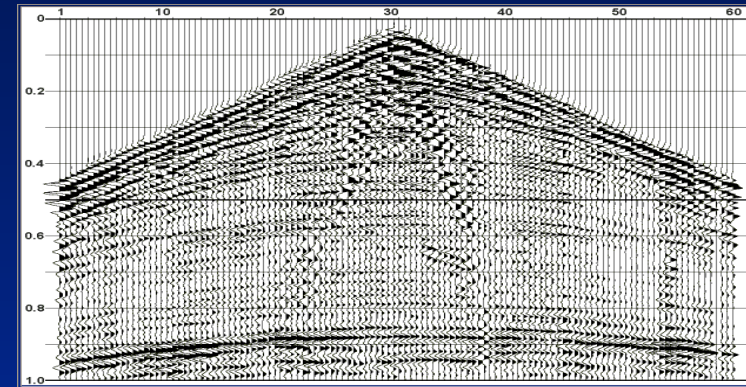
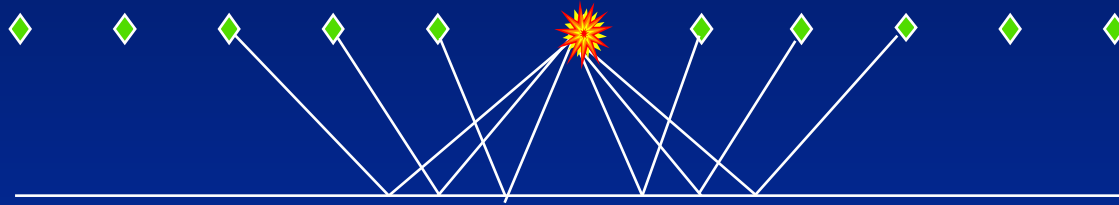
(ie. How far from the source is the cmp generated by group number) 60?

2D Marine layout

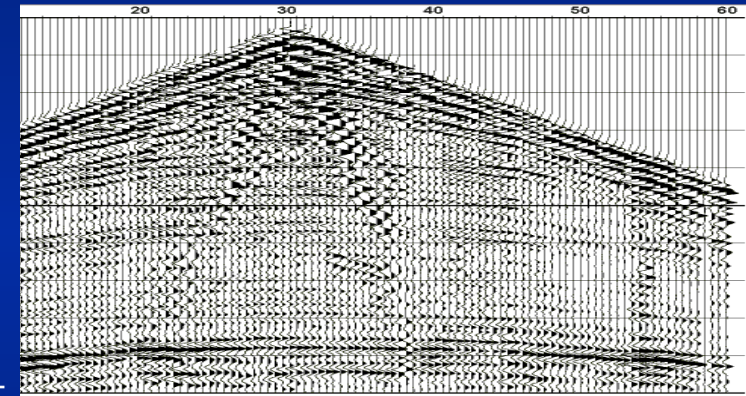
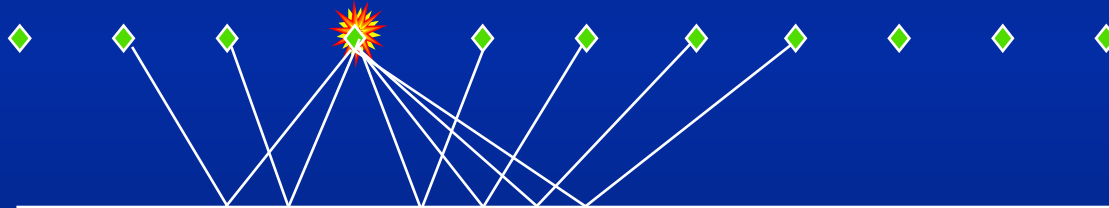


2D Land Field Layouts

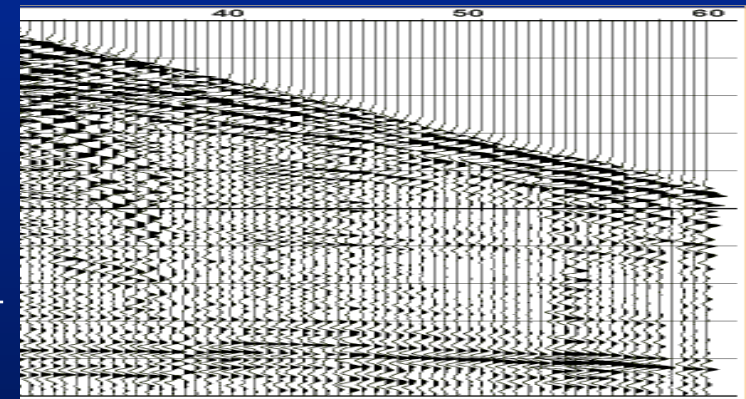
Symmetric split spread



Asymmetric split spread



End on



Calculations

$$\text{CMP INT} = (\text{Groupint}/2)$$

$$\text{Number of NEW cmps / Shot} = (\text{Shot int} / \text{CMP int})$$

NB. True where G.I and Shot interval are integer multiples of each other and 'end-on' shooting. For other configurations, you may have to draw to confirm fold.

$$\text{Fold} = (\text{Groupint}/\text{Shot int}) * (\text{No.channels}/2)$$

$$\text{First live CMP} = [(\text{FTO}/2) / \text{CMP int}] + 1$$

$$\text{first full fold CMP} = \text{first live CMP} + [(\text{fold} - 1) * (\text{no. new cmps per shot})]$$

IN OMEGA THE FIRST LIVE CMP IS USER DEFINED - IT DEFAULTS TO 1!
THIS FORMULA IS APPLICABLE TO SOME OLDER SOFTWARE SYSTEMS

$$\text{with maximum fold} = \text{first live CMP} + [((\text{no.shots} - 1) * (\text{no. new cmps per shot})) + (\text{no. new cmps per shot})]$$

$$\text{MP} = \text{last full fold CMP} + [(\text{fold} - 1) * (\text{no. new cmps per shot})]$$

Calculations

$$\text{CMP INT} = (\text{Groupint}/2)$$

$$\text{Number of NEW cmps / Shot} = (\text{Shot int} / \text{CMP int})$$

NB. True where G.I and Shot Interval are integer multiples of each other.

For other configurations, you may have to draw to confirm fold.

~~In this case, the configuration is 'regular'.~~

$$\text{ld} = (\text{Groupint}/\text{Shot int}) * (\text{No.channels}/2) = (25/25) * (10/2) = 5$$

$$\text{First live CMP} = 1 \quad \text{because we used the Omega default}$$

$$\begin{aligned} \text{first full fold CMP} &= \text{first live CMP} + [(\text{fold} - 1) * (\text{no. new cmps per shot})] \\ &= 1 + [(5 - 1) * 2] \\ &= 9 \end{aligned}$$

$$\begin{aligned} \text{with maximum fold} &= \text{first live CMP} + [((\text{no.shots} - 1) * (\text{no. new cmps per shot})) + (\text{no. new cmps per shot})] \\ &= 1 + [((20 - 1) * (2)) + (2 - 1)] \\ &= 40 \end{aligned}$$

$$\begin{aligned} \text{MP} &= \text{last full fold CMP} + [(\text{fold} - 1) * (\text{no. new cmps per shot})] \\ &= 40 + [(5 - 1) * 2] \\ &= 48 \end{aligned}$$

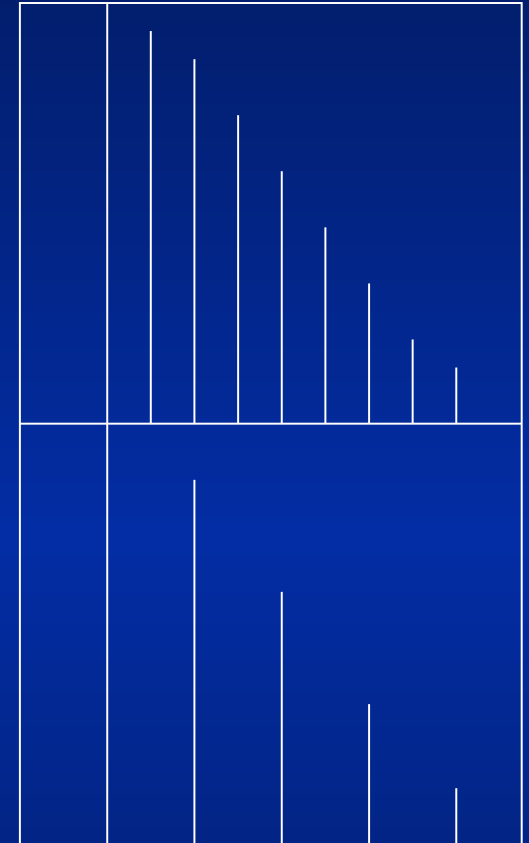
Definitions

Trace Decimation- This process involves reducing the data volume by dropping or discarding traces. Typically every second trace in a shot record is discarded.

Trace Summation- This process involves reducing the data volume by summing adjacent traces.

Trace no

1 2 3 4 5 6 7 8

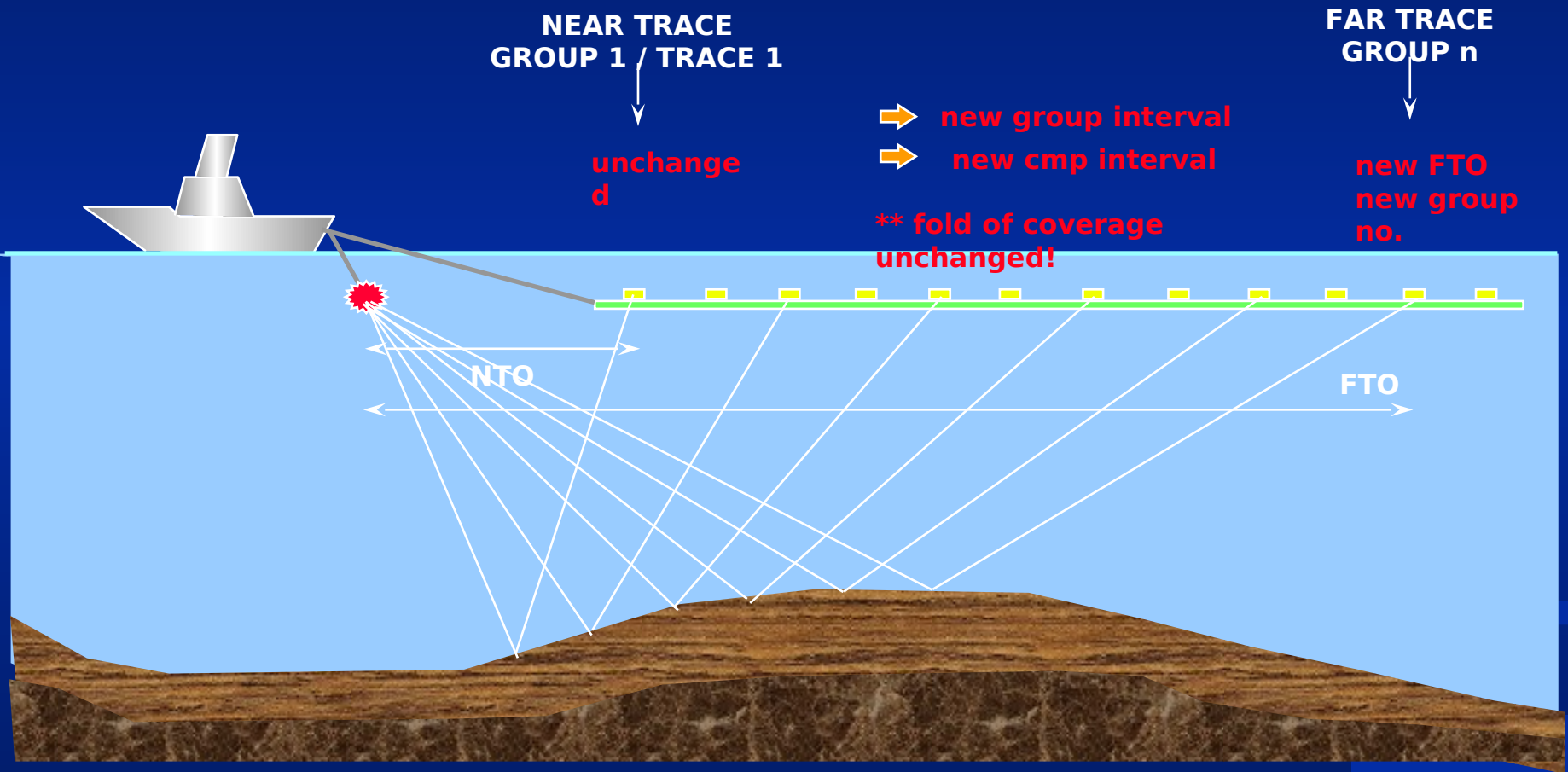


Trace no

1 2 3 4

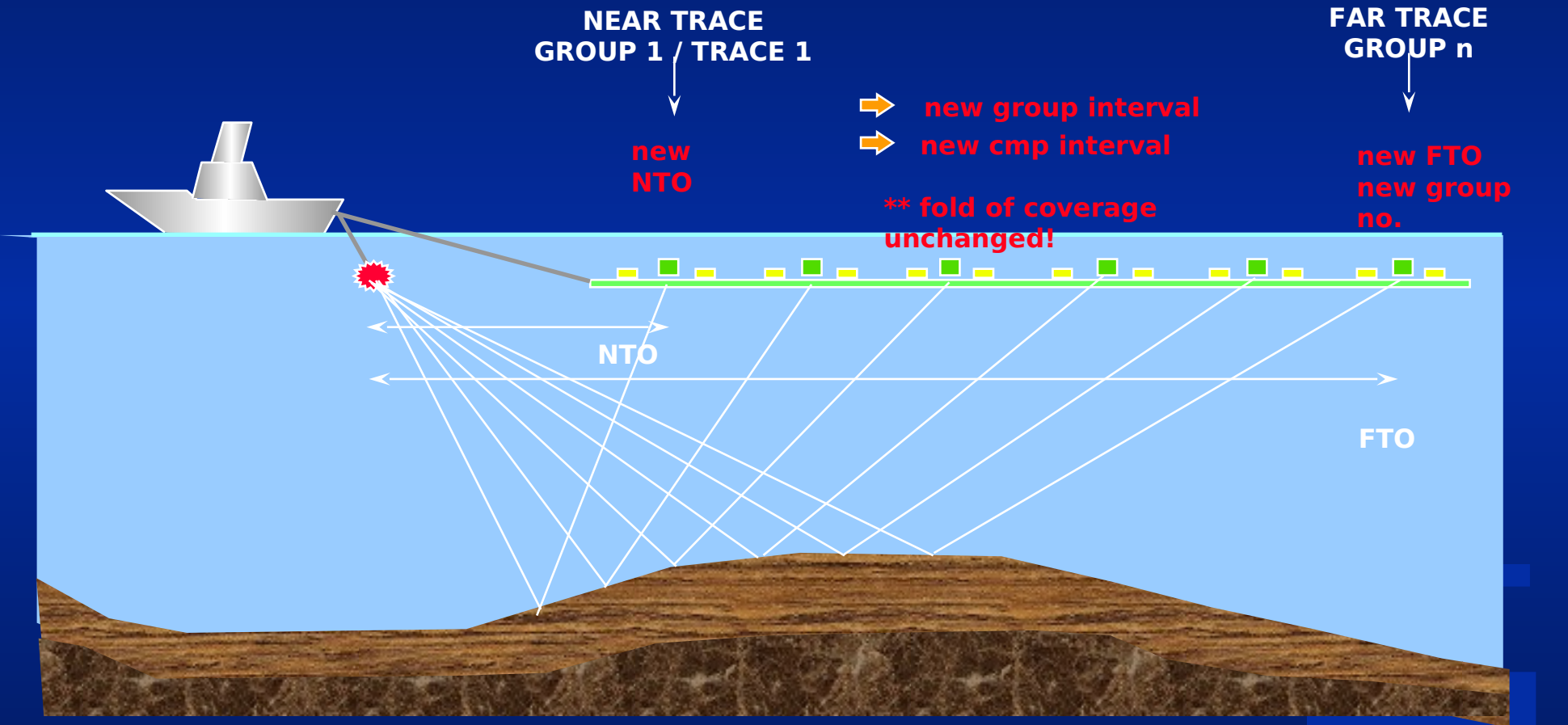
What happens to our geometry

Trace Decimation



What happens to our geometry

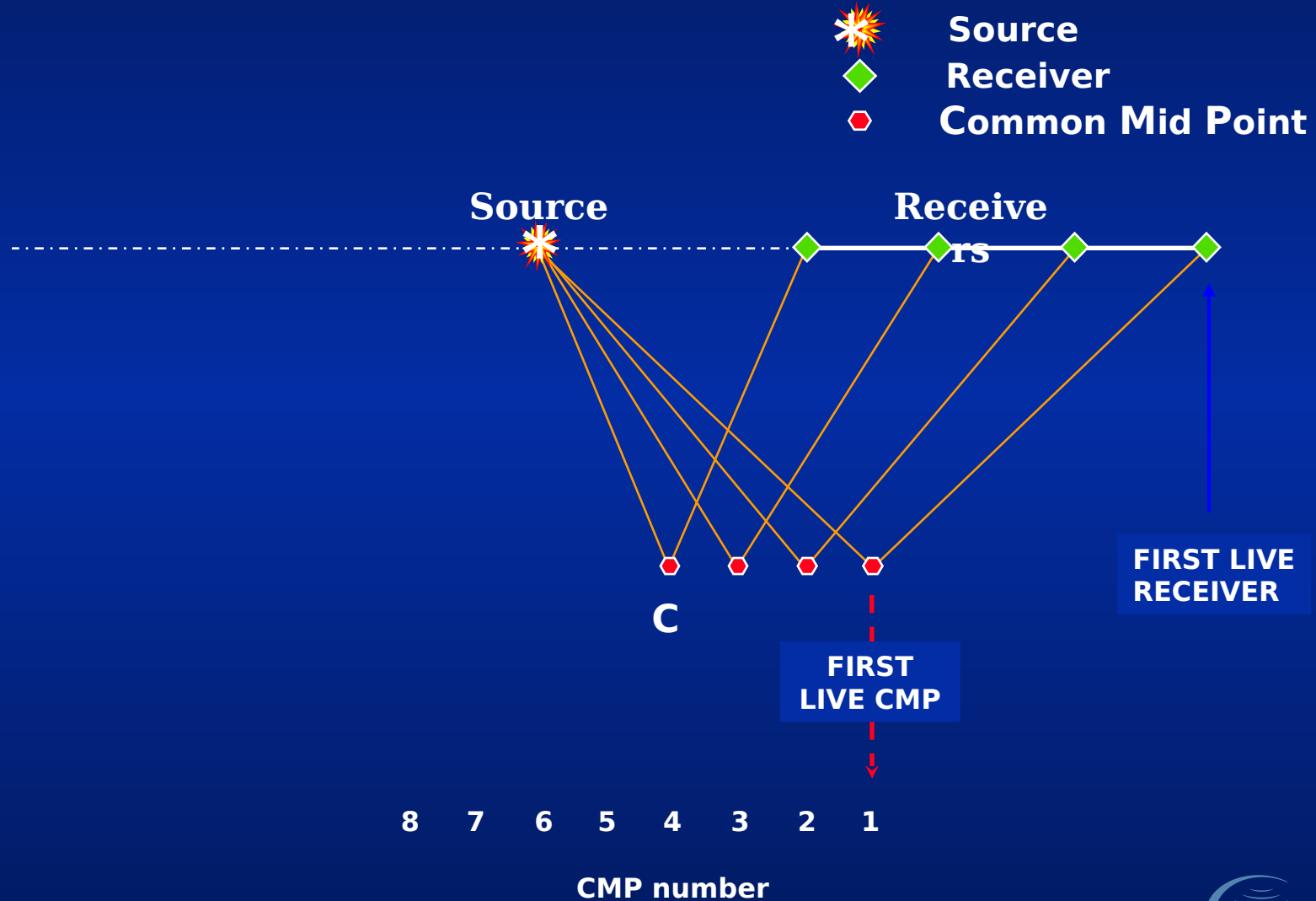
Trace Summation



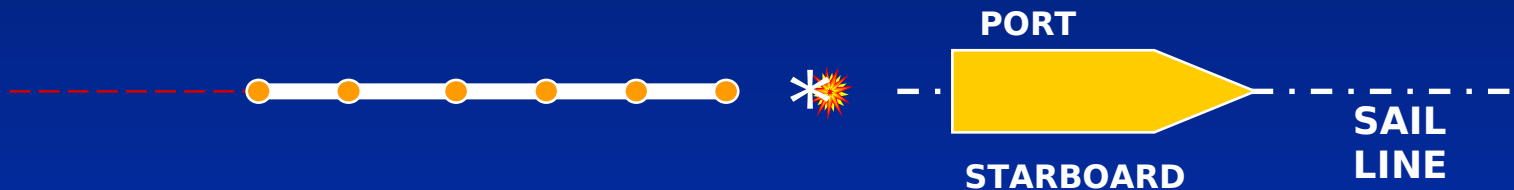
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Basic Marine Geometry

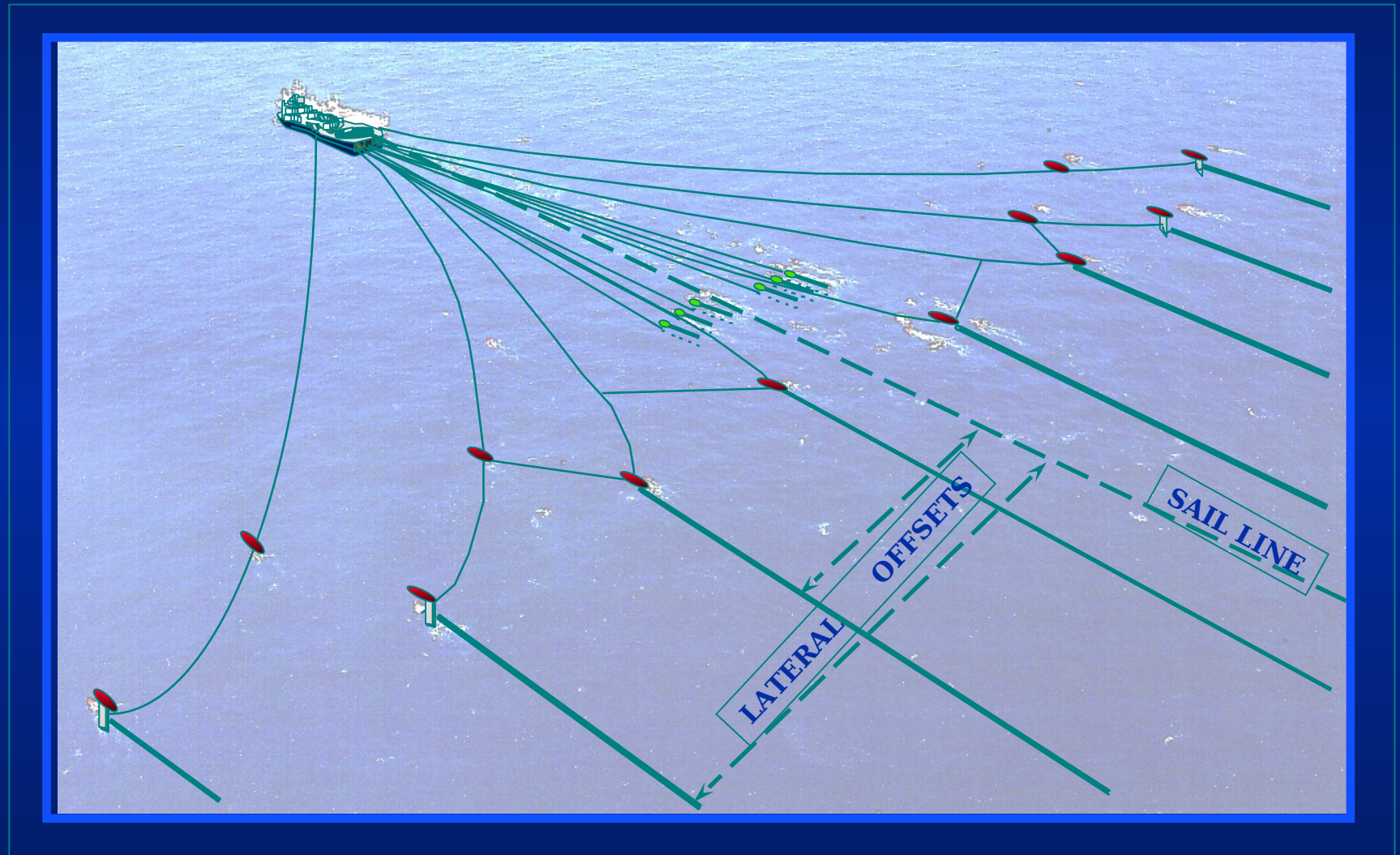


Marine 2D Acquisition



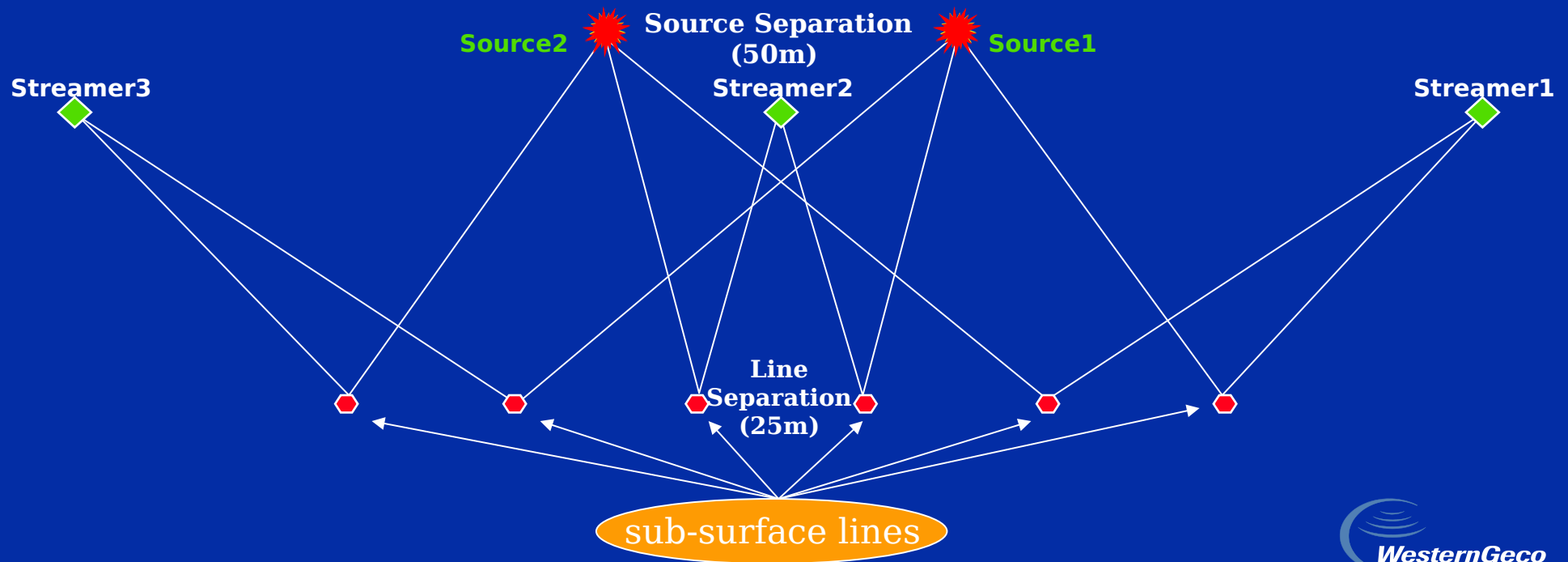
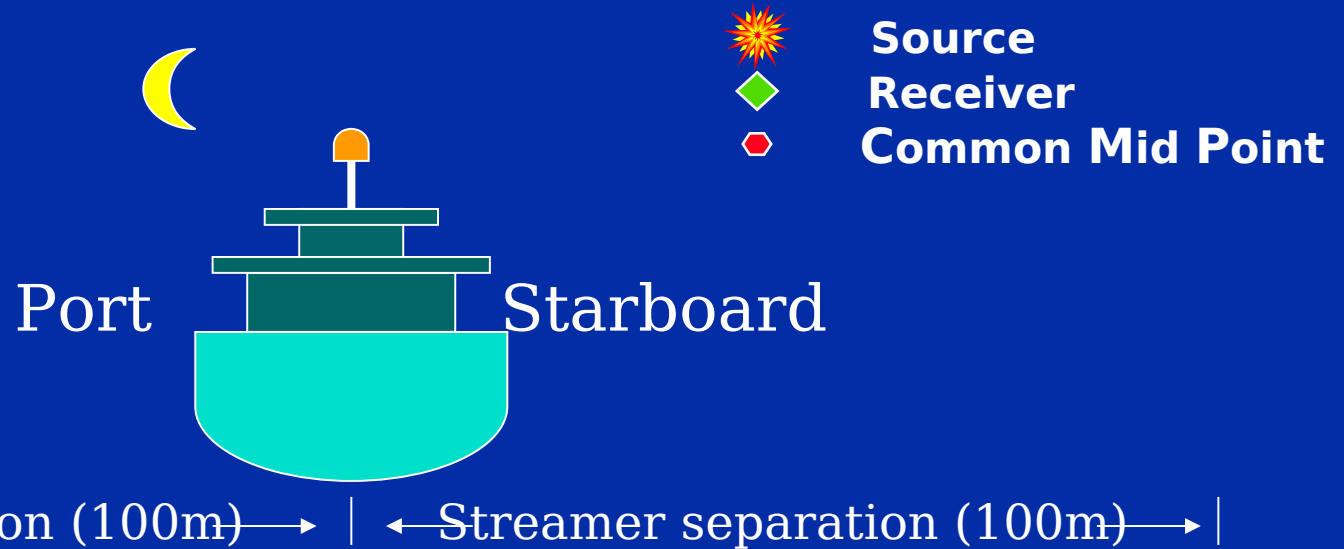
- Produces a series of discrete 2d lines across the survey area
- Lines are Processed separately, although parameters will be the same
- For consistency 'tie-lines' may be recorded producing a coarse grid of information

Marine 3D Acquisition



Marine 3D geometry

- **Single boat**
- **Dual source**
- **Multi streamer**



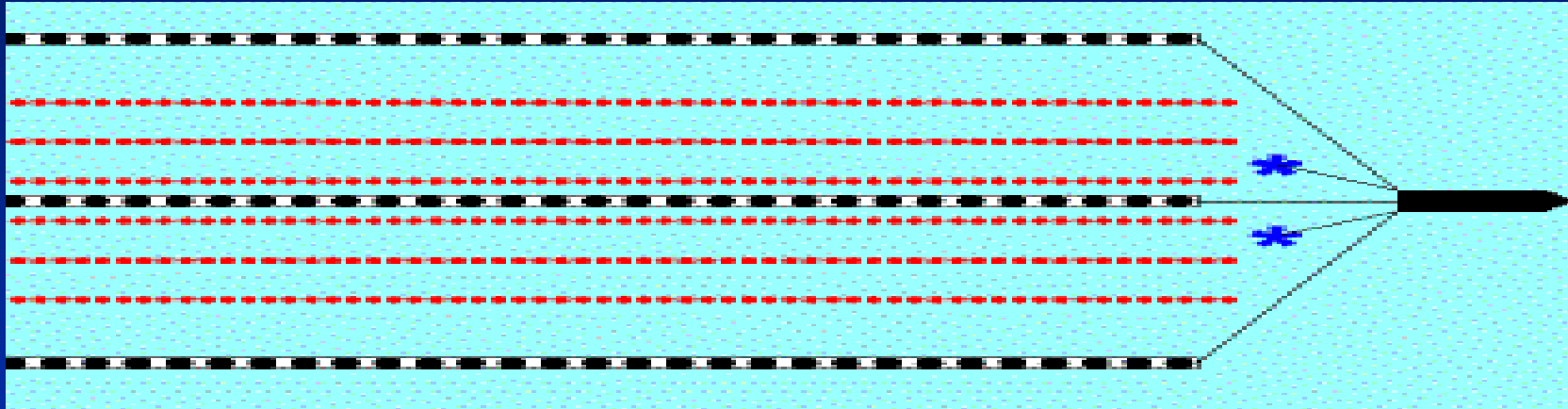
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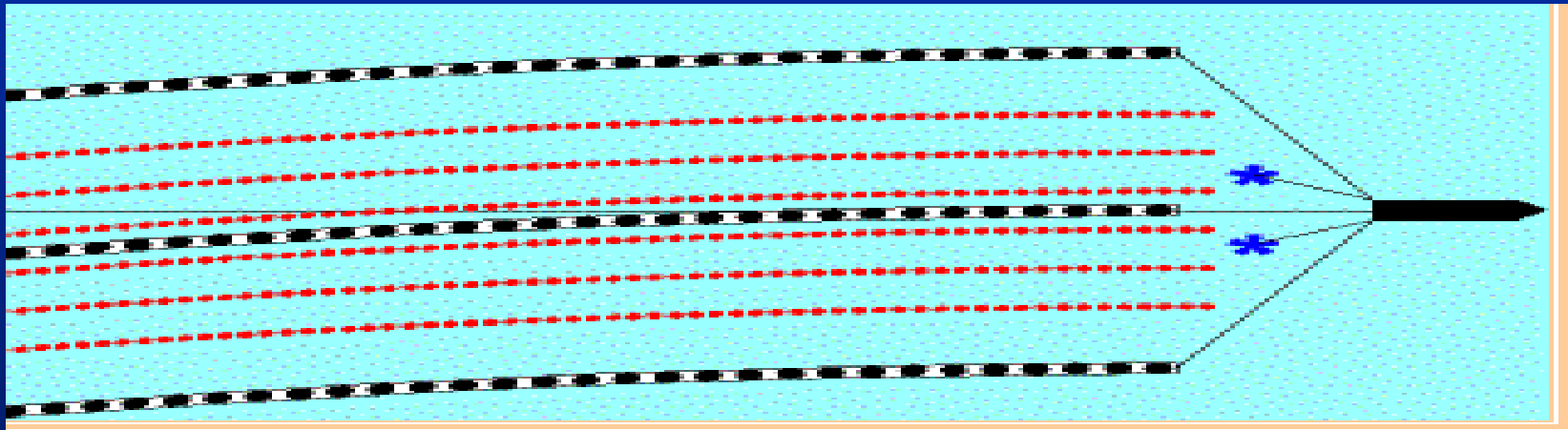
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Cable Feathering

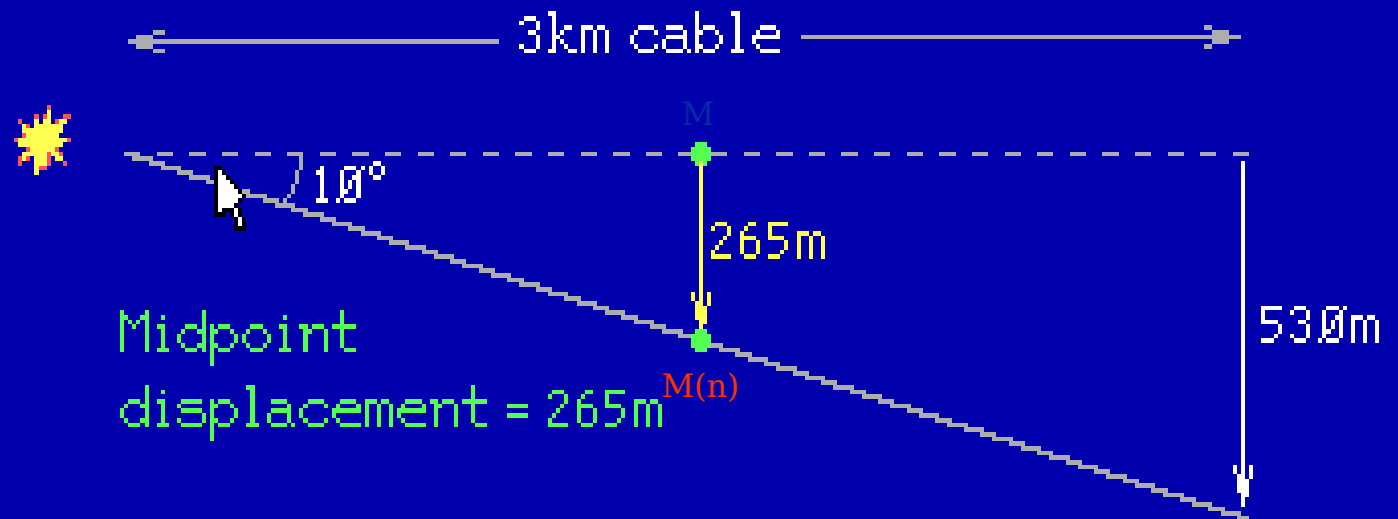
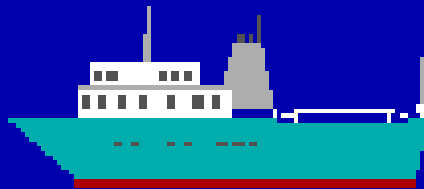


No feathering



Feathering

The Real Effect of Feathering



If the marine cable is feathered by 10 degrees, the far end of the cable will be displaced by **530m** from the nominal straight shooting line.

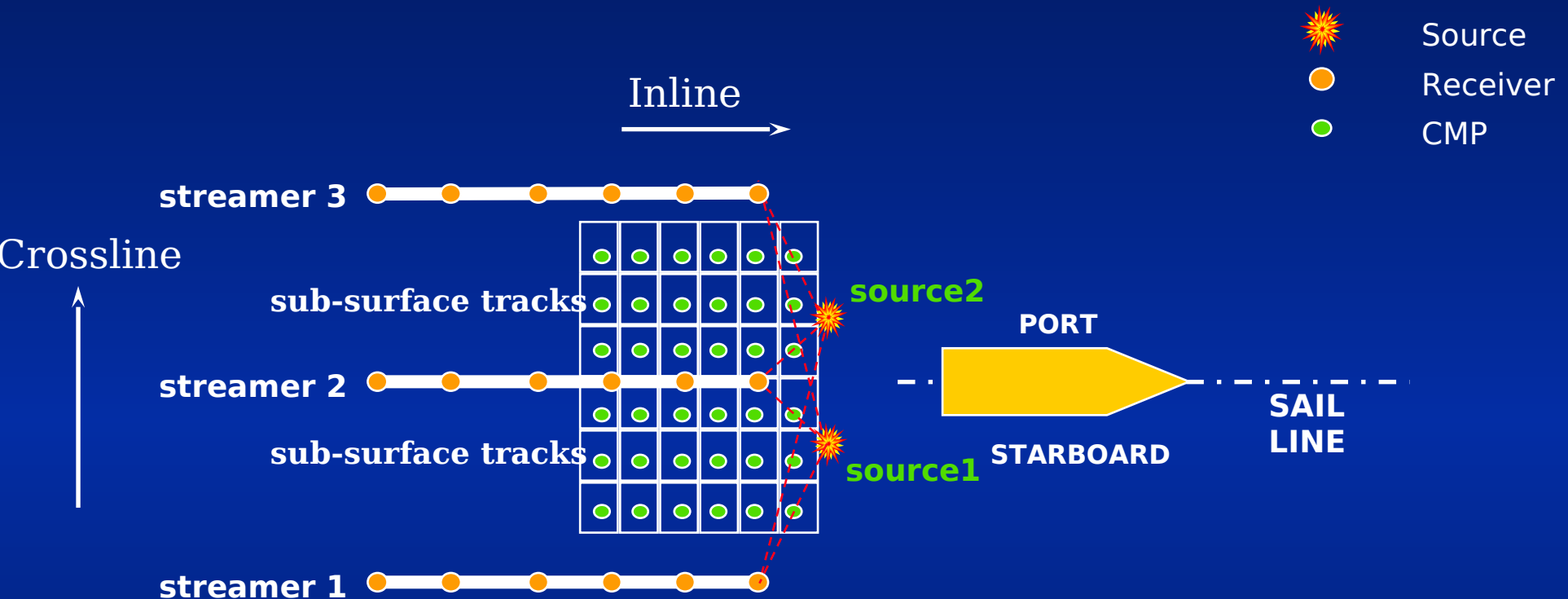
This causes the midpoints to be displaced by 265m.

Classifications of Geometry

Nominal layout

Projected co-ordinates

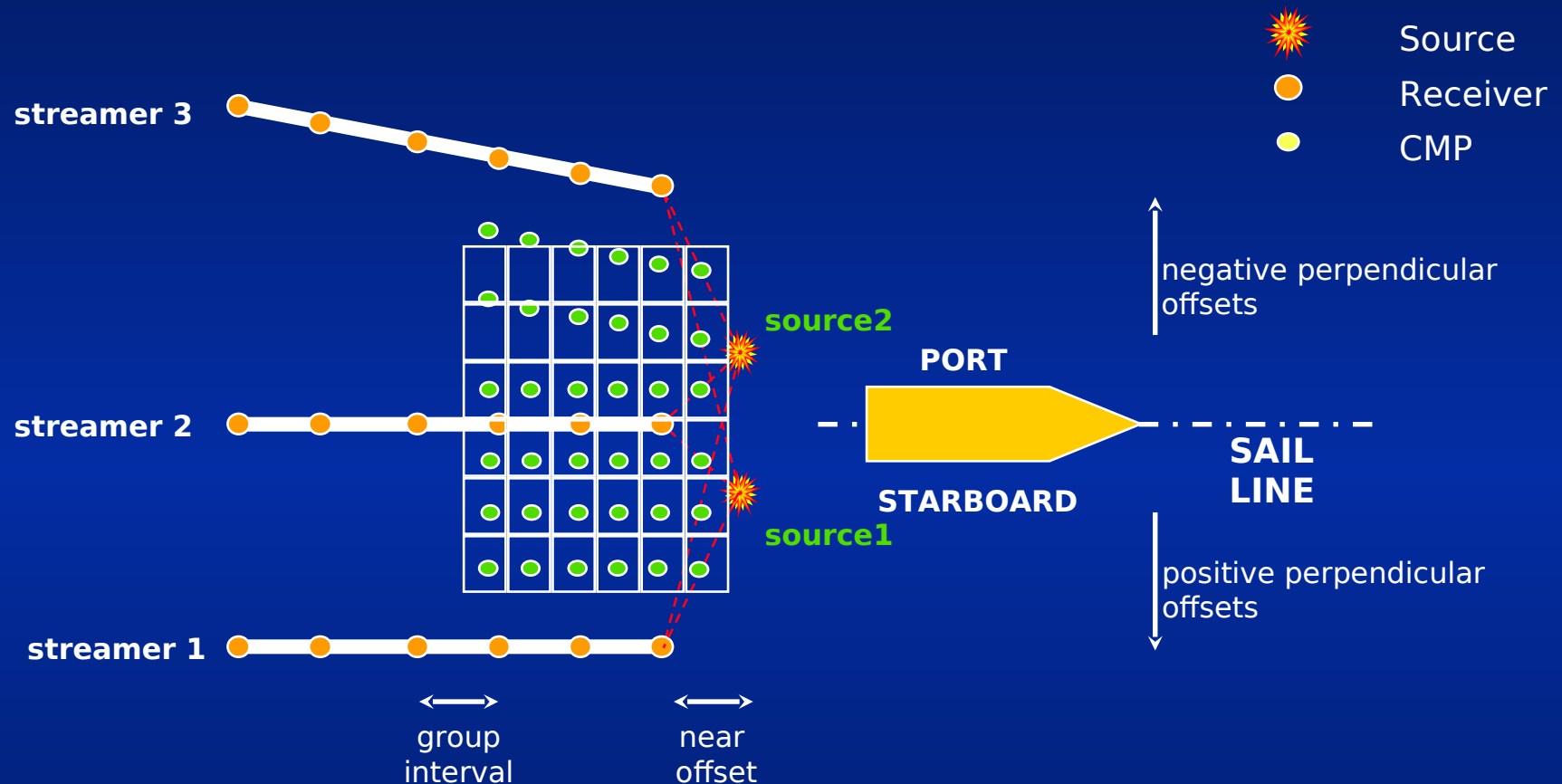
Nominal Layout - Example



- Multiple subsurface lines are recorded each pass of the boat
- Data forms a finely sampled volume of information.

A Grid of bins is overlaid, each cmp position falling at the centre of a bin

Projected Co-ordinates - Example

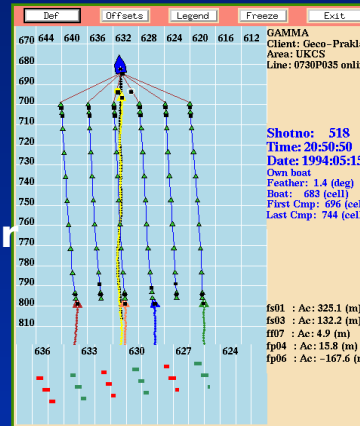


In this exaggerated drawing of cable feathering, it is obvious that mid-point scatter needs to be sorted out (via binning process) and properly Quality Controlled

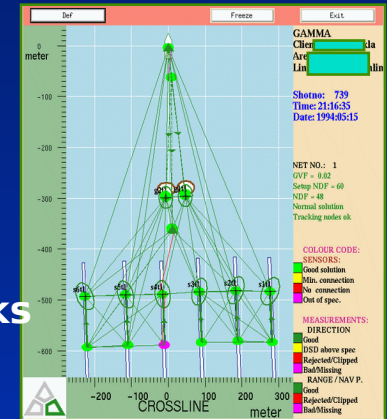
Real-Time Binning



Streamer
shape



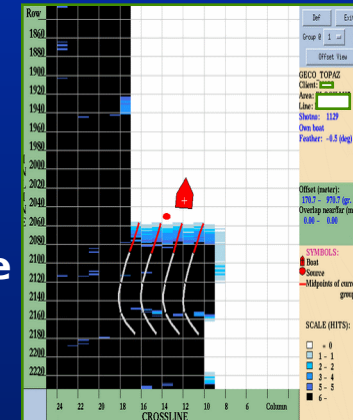
In-sea
Networks



The ability to monitor fold of coverage during the acquisition stage.

In some cases, the Navigators steer the Vessel, and hence the CMPs. In other cases, in-fill lines are shot if necessary to improve the level of fold in each bin.

Coverage
plot



Session Flow:

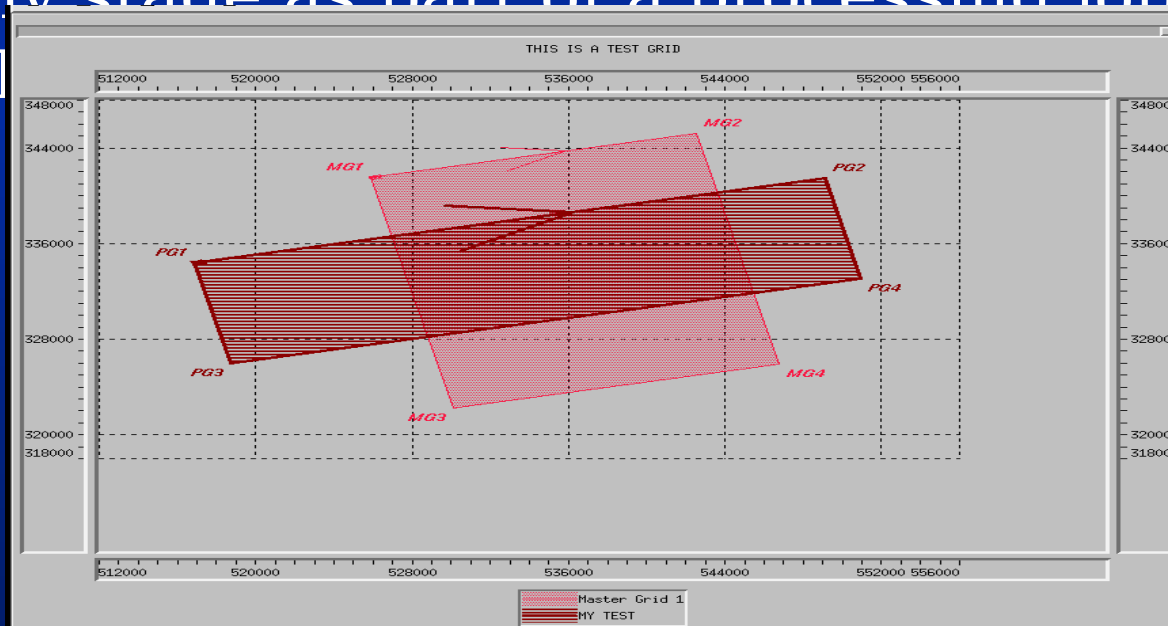
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3-D Grids

Once X / Y coordinates are in the trace headers, processing grids can be defined, or redefined, at any stage as part of a processing job using G1



The Master Grid

**The Master Grid is the basis of a 3D grid definition.
There are 3 parts to a Master grid Definition:**

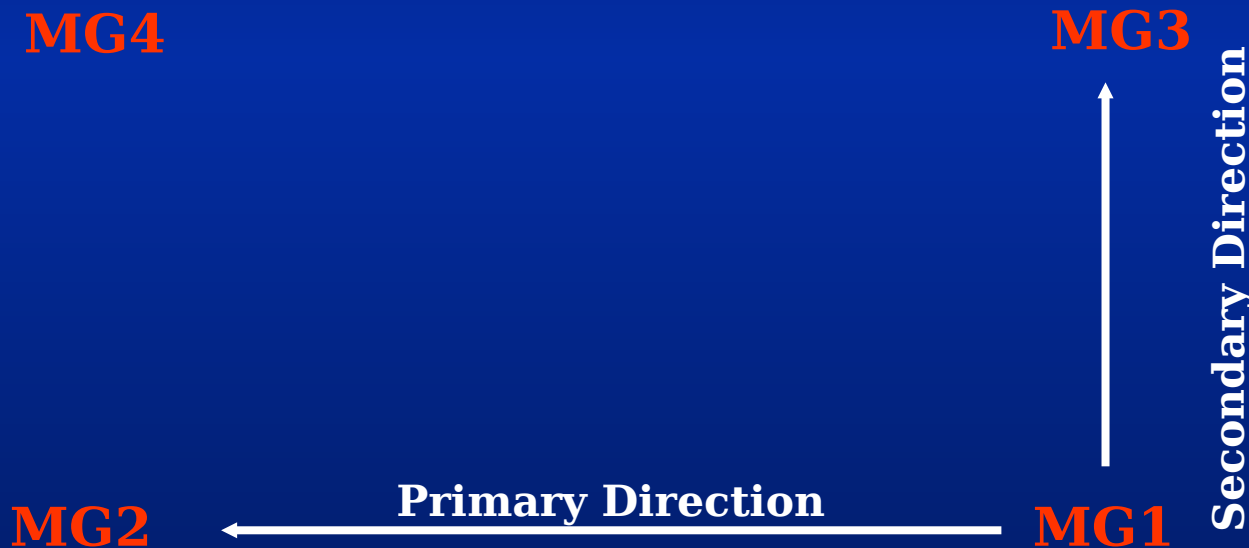
the X/Y coordinates that define the location and extent of the grid

the dimensions of the cells (bins) within the grid

the specification of the ordinals

Defining Corners of Master Grid

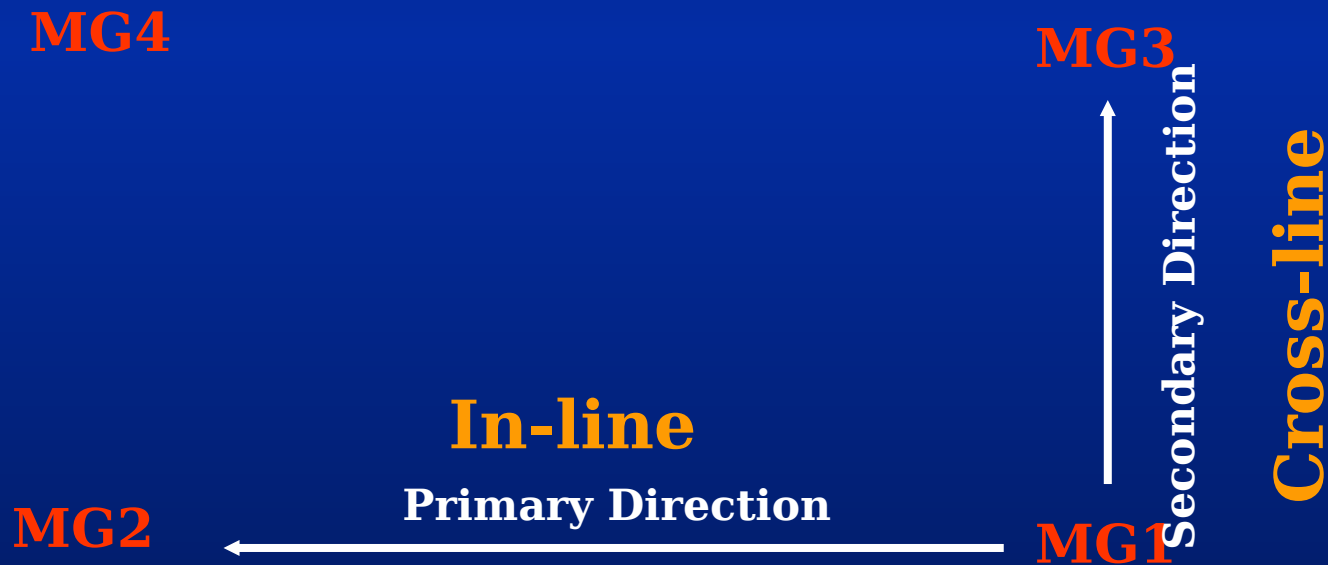
extent of the Master Grid is defined by specifying four p
centre of each corner cell is defined



Other Names for Grid Axes

In common usage, the direction of the Primary Axis is called the “in-line” direction. The axis is sometimes called the “shot” direction.

Otherwise, the Secondary Axis is referred to as the “cross-line” direction. These terms vary among and within companies.



Defining Ordinals

Ordinals are defined by specifying the Primary and Secondary Ordinals to associate with the centre of the corner cell containing the point. Increments between ordinals at adjacent cell centres are defined.



ORDINALS

- **Primary ordinals always increase from MG1 to MG2**
- **Secondary ordinals always increase from MG1 to MG3**
- **Ordinal increments are therefore always “positive”.**
- **Ordinal values may be positive, negative or zero.**

Defining Cell (bin) Numbers

Cell number order is defined by specifying the starting corner cell, and the grid axis.

PG4 12	11	10	PG3 9	3.0
8	7	6	5	2.0
4 PG2	3	2	1 PG1	1.0
40.0	30. 0	20.0	10.0	

BINNING

Problem

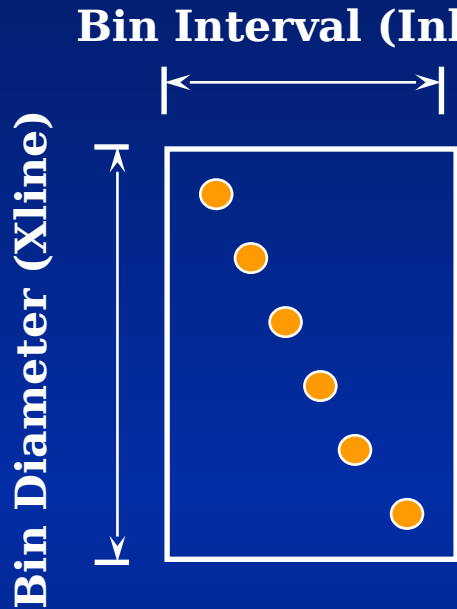
m
Fold variations and irregular offset distributions within CMP bins reduce the effectiveness of stacking

Solution

Analysing bin contents via a 3D database, and making adjustments (where necessary via Flexi-binning) to achieve a high degree of consistency in fold and offset distribution

The ideal binning strategy optimises stack quality without introducing excessive lateral smear

BINNING



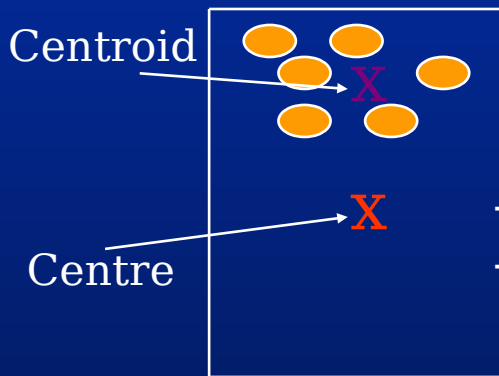
The contents of a Bin

Each Bin contains a collection of midpoints (CMP's)

The midpoints within a bin will be stacked together.

There are two attributes for a stack trace:

- a) Bin Centre
- b) Bin Centroid - An average of co-ordinates



Ideally we have the nominal fold of coverage (in this case 6) and each midpoint is from a different offset group

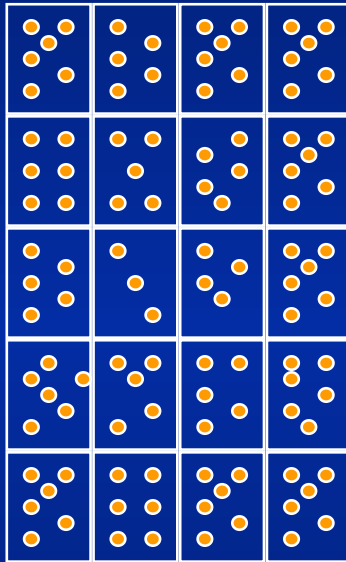
This is not likely to be the case for all bins in a survey.
There may exist irregular offset distributions and low and/or over fold areas

BINNING OPTIONS

- CONVENTIONAL BINNING
- FLEXI-BINNING

Conventional Binning

Data is binned as acquired



- Each **CMP** location falls into a bin of nominal bin size
- All traces are accepted

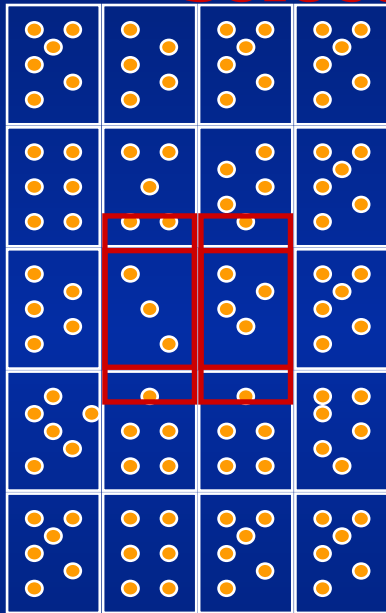
Results:

- Variation of fold
- Irregular offset distribution
- Crossline scatter of midpoints within bins

This often results in lateral variation in fold, and thus reduced effectiveness of processes such as velocity analysis and stacking.

Flexible Binning

Data is binned by intelligent search and selection



- Bins are allowed to expand only until the gaps in offset distribution are filled
- The expansion is allowed only up to a specified maximum
- Traces are assigned to and used in both bins

Results

- Fold is increased
- Offset distribution is optimised
- Lateral smear reduced to a minimum

Flexi-Binning

- Flexi-binning is primarily used in marine processing to regularise fold of coverage on pre-stack data.

Cable feather is mainly responsible for uneven fold.

- Improved fold leads to:
 - better multiple attenuation
 - improved normalisation within stack
 - more constant signal-to-noise ratio
 - reduced problem of zero-stackwords pre-

Dual Purpose Operation

m is to have each offset represented in each cell (bin)

exi-binning performs two operations:

Reject (or down-weight) duplicate traces

Copy traces from adjacent cells (bins) to account for missing traces

Results of 'borrowing' a trace

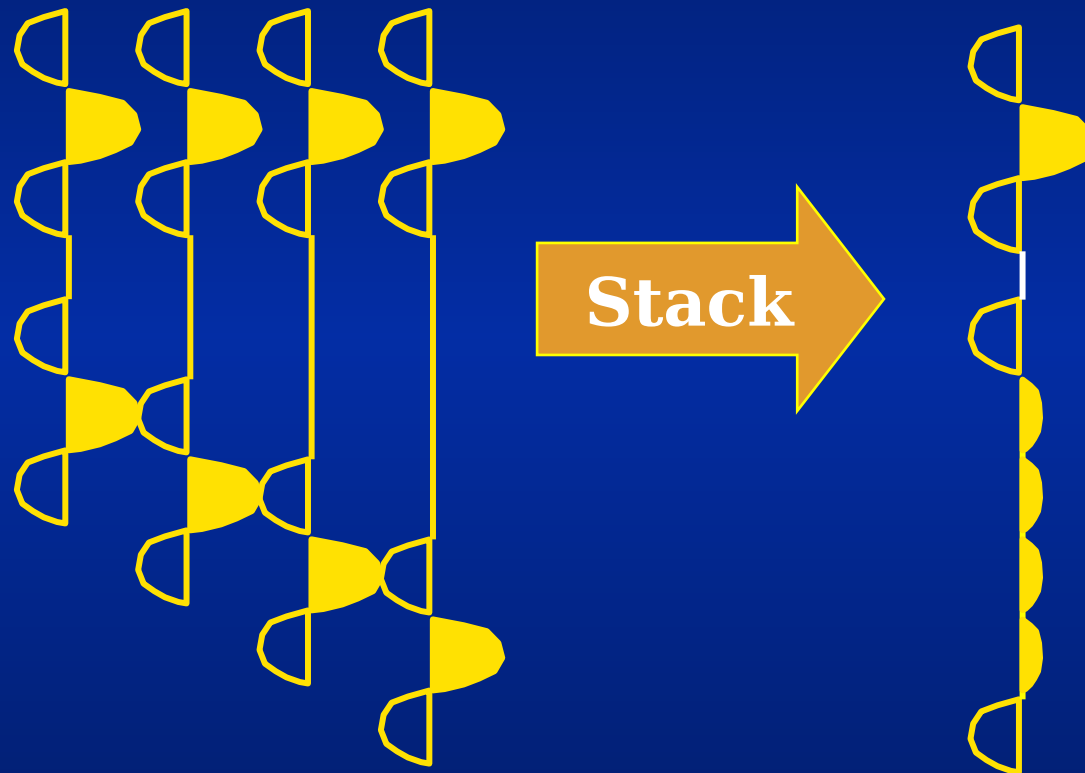
If a trace is copied for use in another cell
two things happen:

- it is still available for use in its own (prime) cell
- the data is copied, and the trace header values adjusted such that the midpoint falls at the centre of the new cell

Example of good offset distribution (enabling good multiple attenuation)

Primary

Multiple

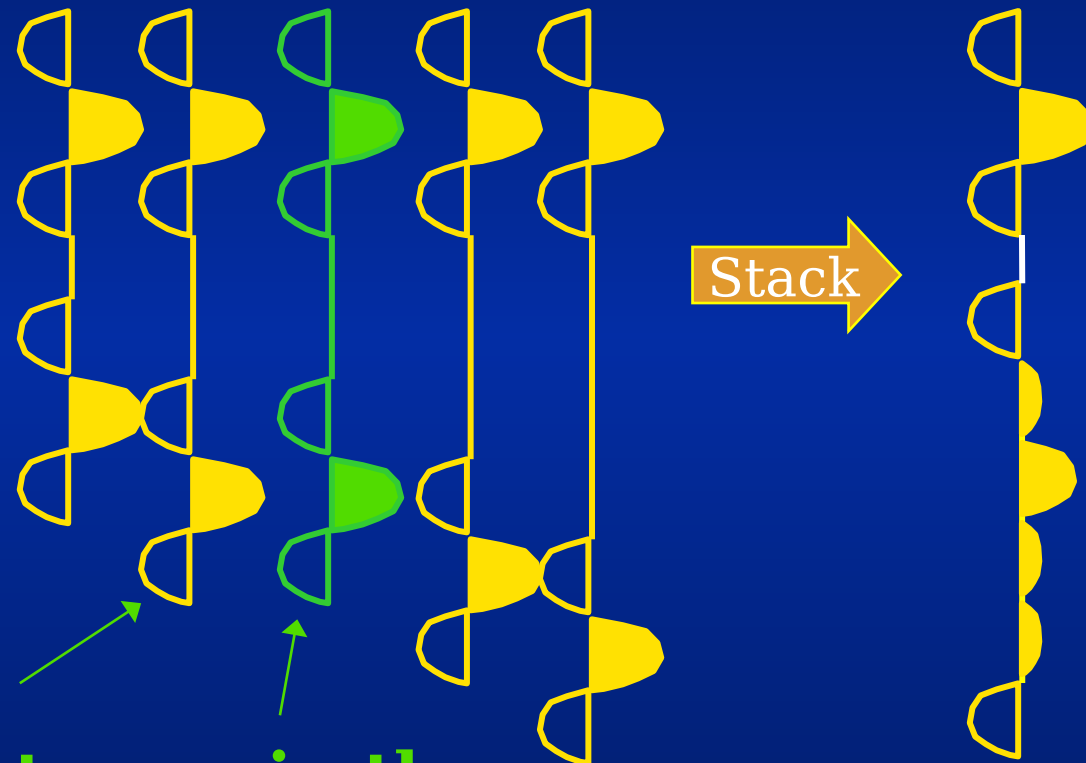


(After NMO corrections)

Example of bad offset distribution (multiple attenuation not so good)

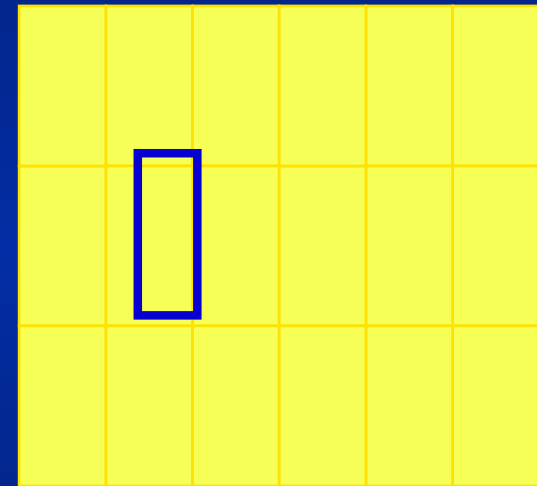
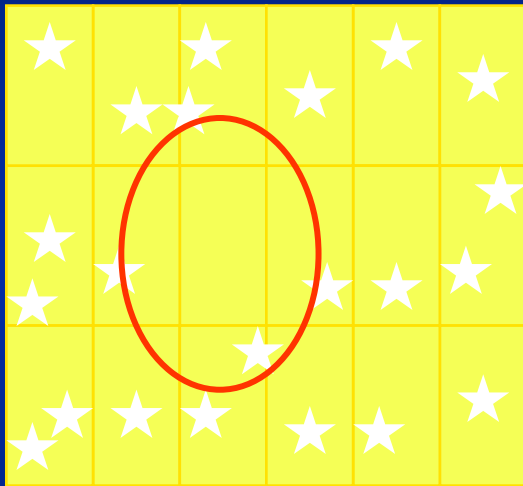
Primary

Multiple



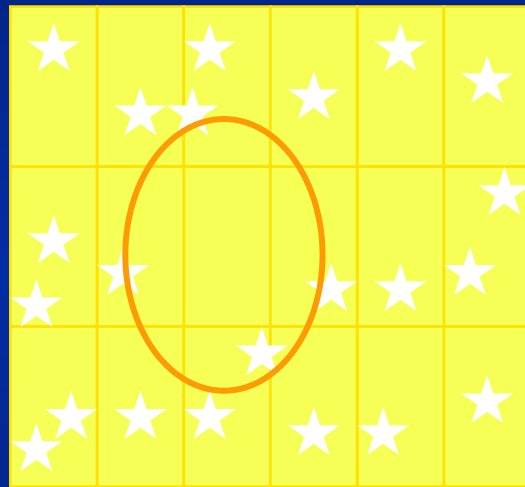
**Two traces in the
same offset segment**

Flexi-binning on an offset plane

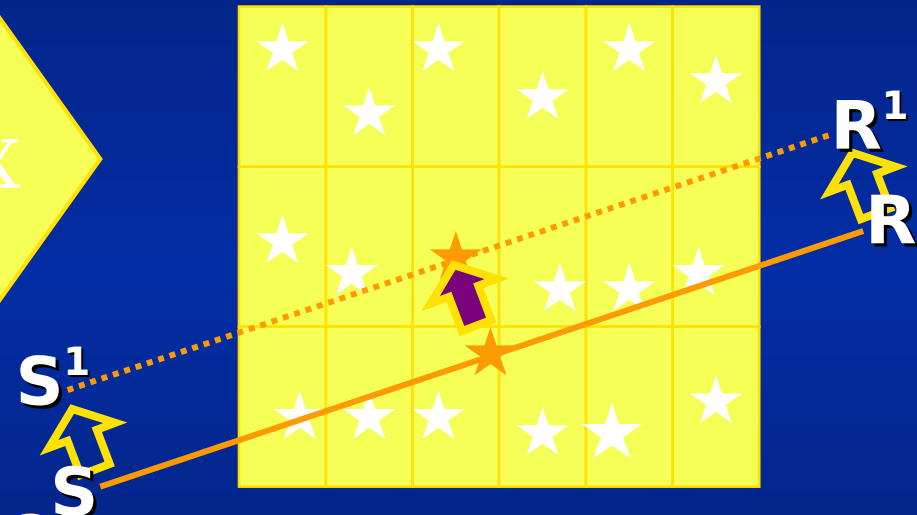


Input
Identify empty cells

Flexi-binning on an offset plane



Input
Identify empty cells



Output

1. Missing bins use cell expansion to nearest trace then "copy & move" (plus header translation)
2. Duplicate traces in bins removed

Binning Example

Conventional Binning

What is the Fold in A? 42

What is the Fold in B? 16

What is the Fold in C? 46

The nominal fold expected is 36.

Has this level been met?

Flexible Binning

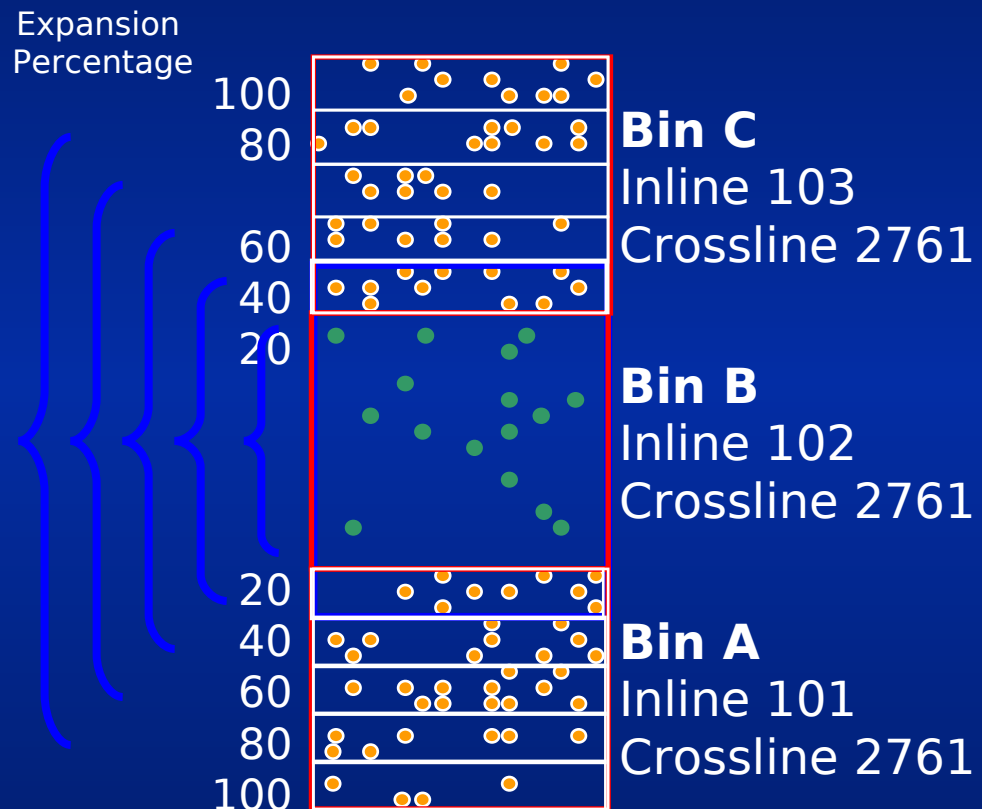
How much should Bin B expand?

40% (20% Overlap)

36

What is the Fold in B? _____

(assumed unique offsets.)



Golden Rule of Flexi-binning

A trace is only copied from the expanded cell if an equivalent trace doesn't already exist in the primary cell.

So, even if the expanded cell is large, it's full extent is very rarely used.

We stress this to clients who are concerned about

introducing smearing to their data

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- Define the term 'coverage plot (aerial map)' as used during binning.

QC of Binning

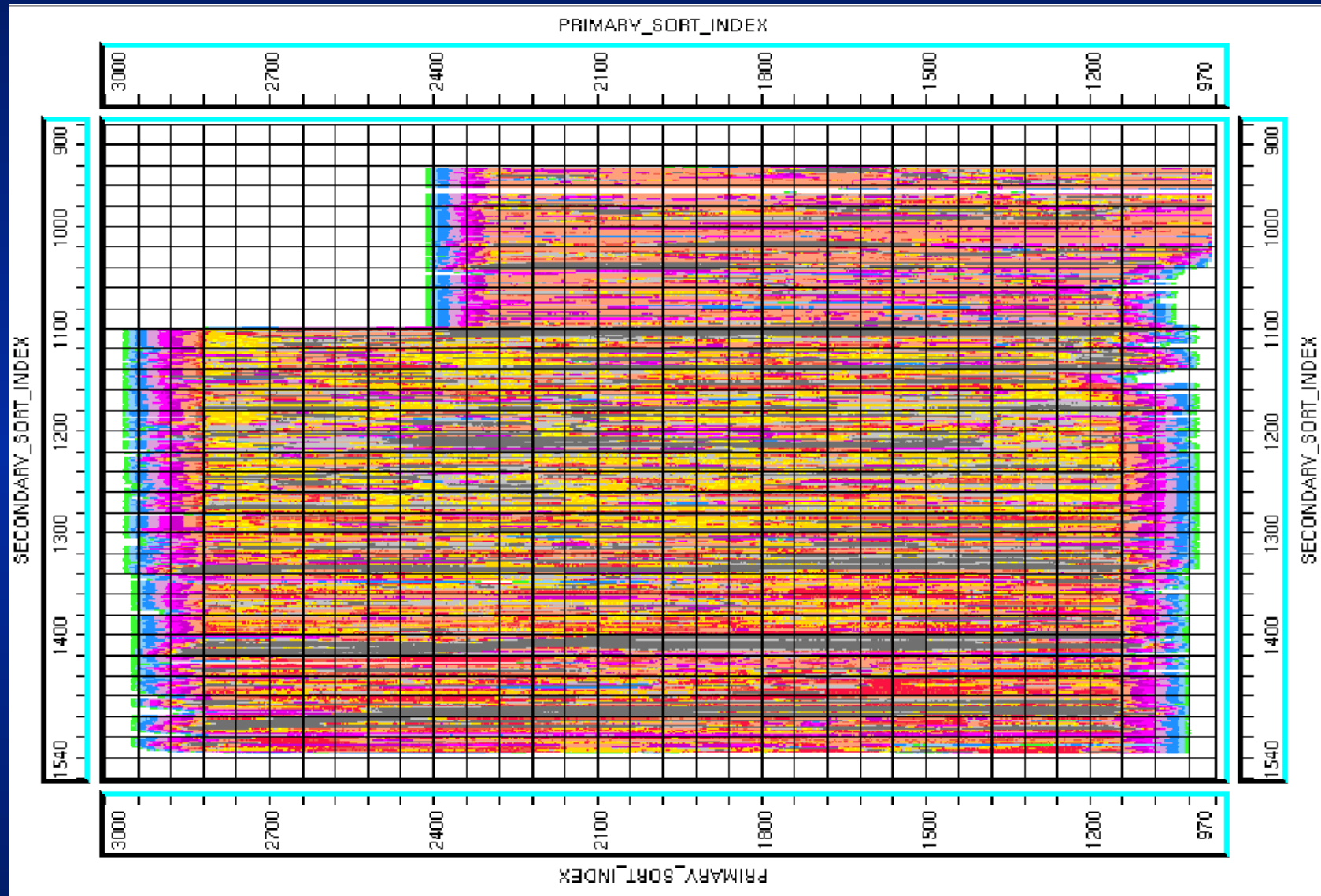
BINNING

Fold of coverage plots

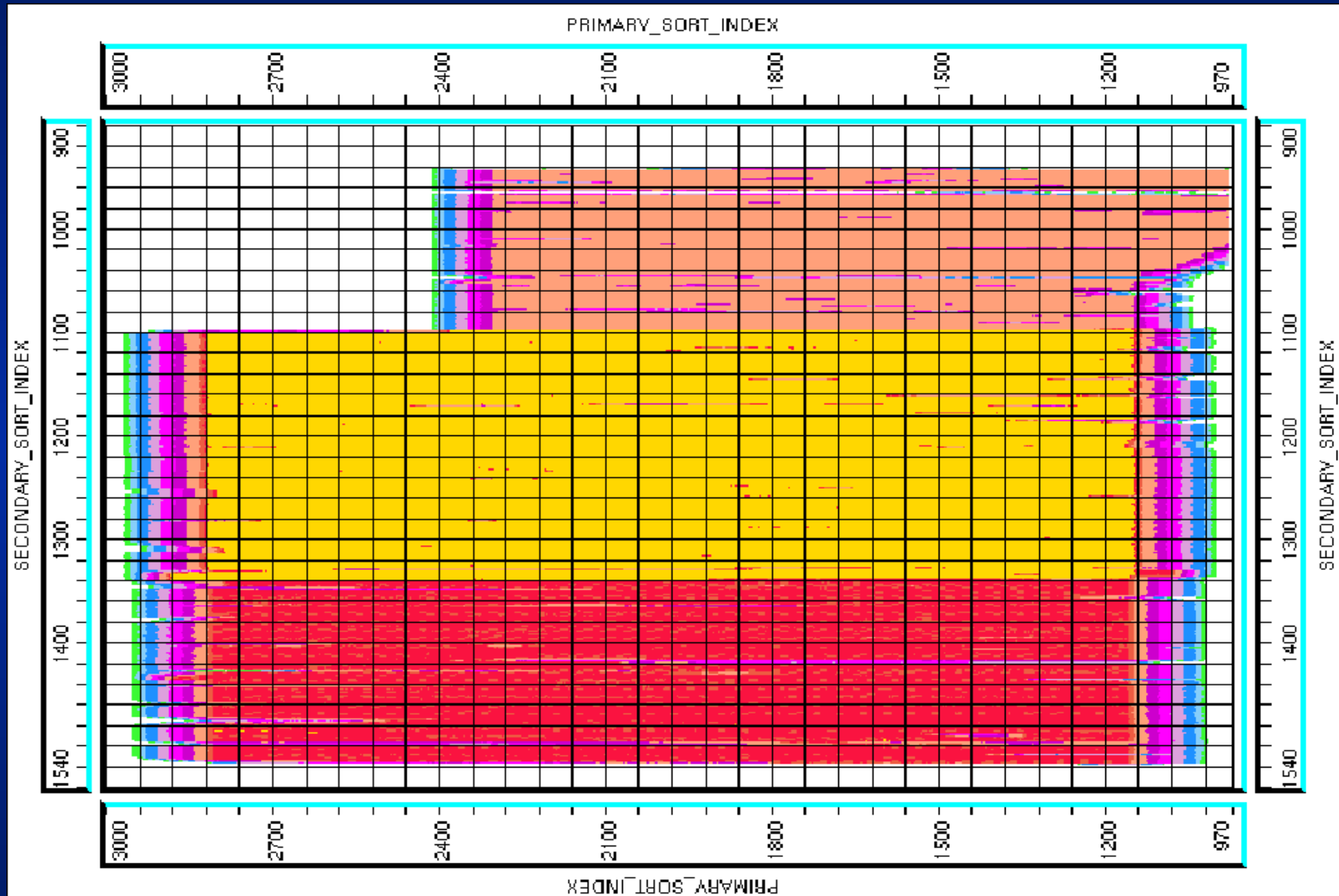
SEISMIC QC

Inline and Crossline gathers and stack displays

Fold of Coverage Plot - Before Flex

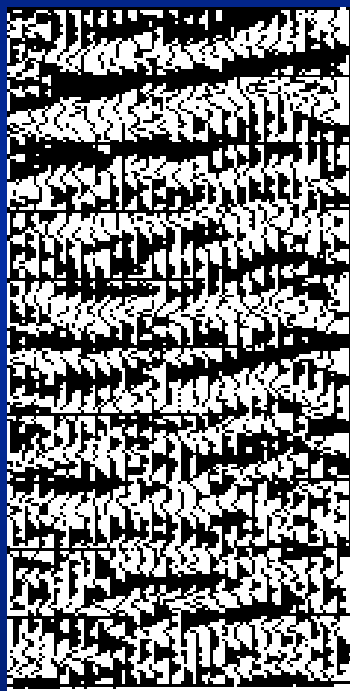


Fold of Coverage Plot - After Flex

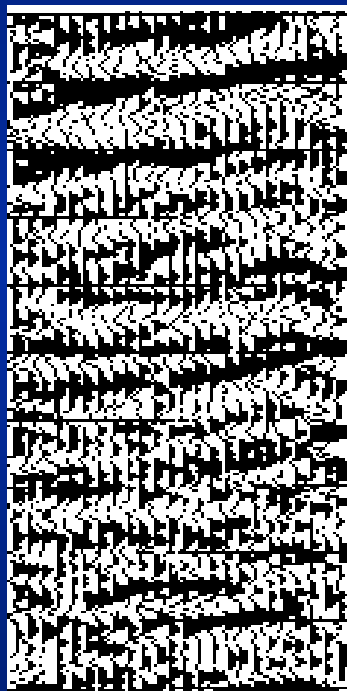


QC of Binning

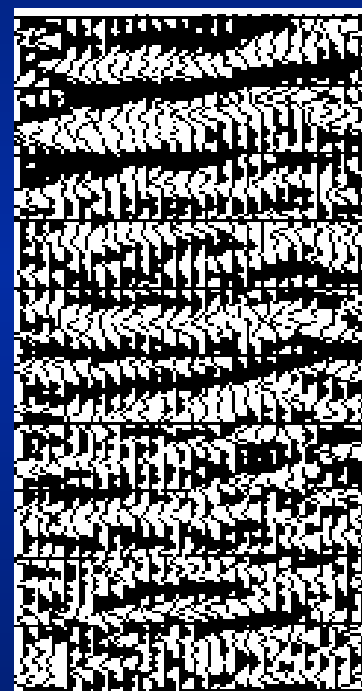
Conventional
25m bins



Flexi-binning
37.5m bins



Flexi-binning
50m bins



Major Binning Considerations

- **Accurate Surveying is very important**
- **Each Bin must have uniform distribution of offsets**
 - Only Short offsets - Useless for Multiple Attenuation
 - Only Far offsets - Jeopardizes Velocity Analysis
- **Greatest density of midpoints (ideally) at Bin Center**
- **Minimize Src-Rcvr Azimuths in significant dip areas**
- **Bins can vary in Xline direction, but usually not in**

3D STACK

Stack data is eventually stored on disk or workstation for 3D interpretations

3D Stacking is the summation of midpoints within a bin to form a stacked trace at the bin centre.

Stack is the most effective method for improving the signal to noise ratio of seismic data.

STACK QC

QC During Stack

Crossline stack displays check for

- progress of stack
- positioning and timing errors
- amplitude variations
- tidal variations

Fold plots

- provides daily monitoring of stack progress
- shows number of traces that remain to be stacked, by using information from binning database.

STACK QC

QC After Stack

Inline displays

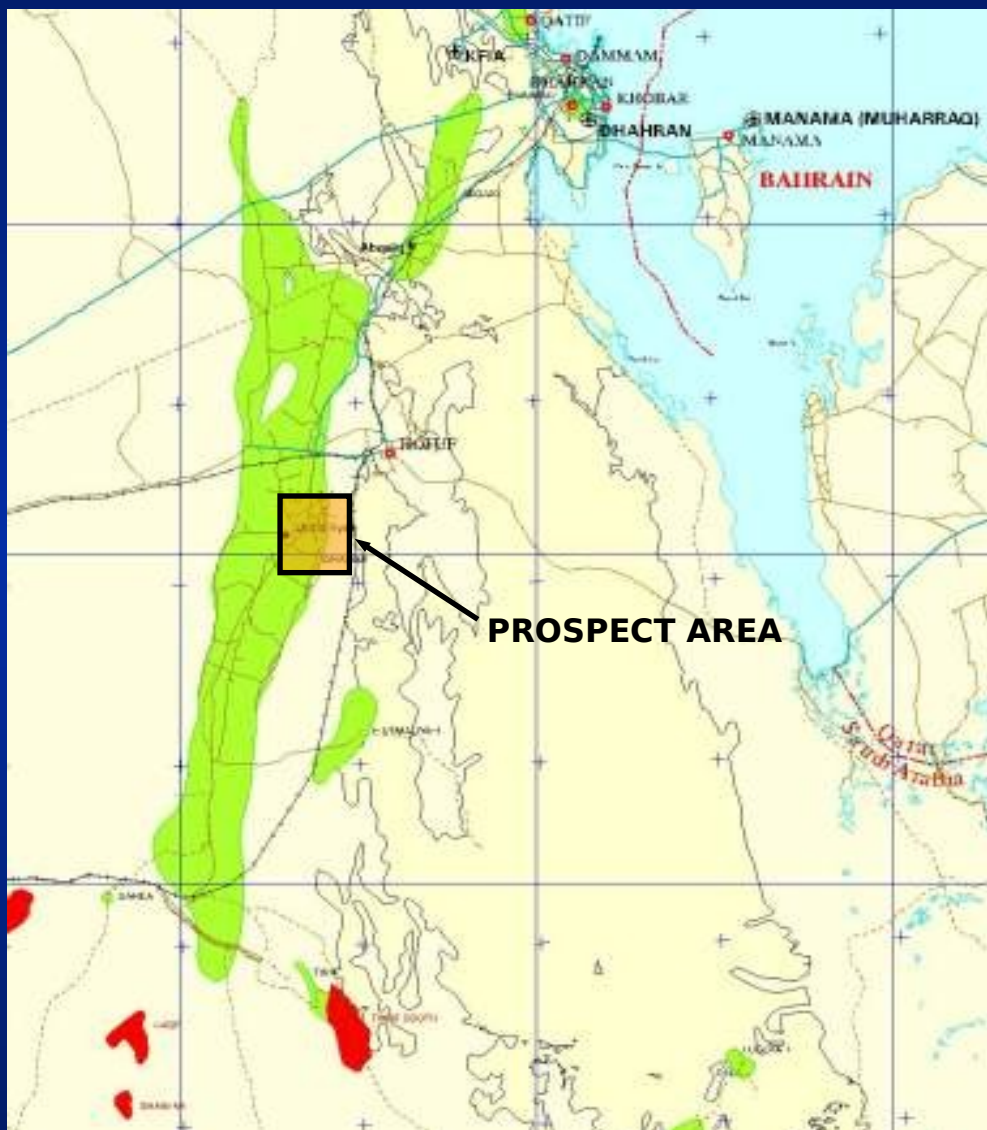
- all inlines to be displayed
- match to pre-stack trials
- check for spikes or noise problems

Crossline displays

- selection of crosslines to be displayed
- check for timing jitter
amplitude variations
structure discontinuities

Isotime displays - **Time-slices**

A Land 3D Survey in Saudi Arabia



RECEIVER PARAMETERS

12 Active Receiver Lines - Spaced 200m Apart

192 Live Geophone Stations (Channels) per Line

50m Geophone Station Interval In-Line

50m x 50m Geophone Pattern

6 Geophone Strings per Station

12 Geophones per String

Each Receiver Line = $192 \times 50\text{m} = 9.60\text{Km}$ Long

12 Lines Spaced at 200m = 2.4Km Wide

“LIVE” Spread Covers an Area of 23.04 Sq Kms

SOURCE PARAMETERS

2 Fleets of Vibrators

5 Active Vibrators per Fleet plus 1 Spare

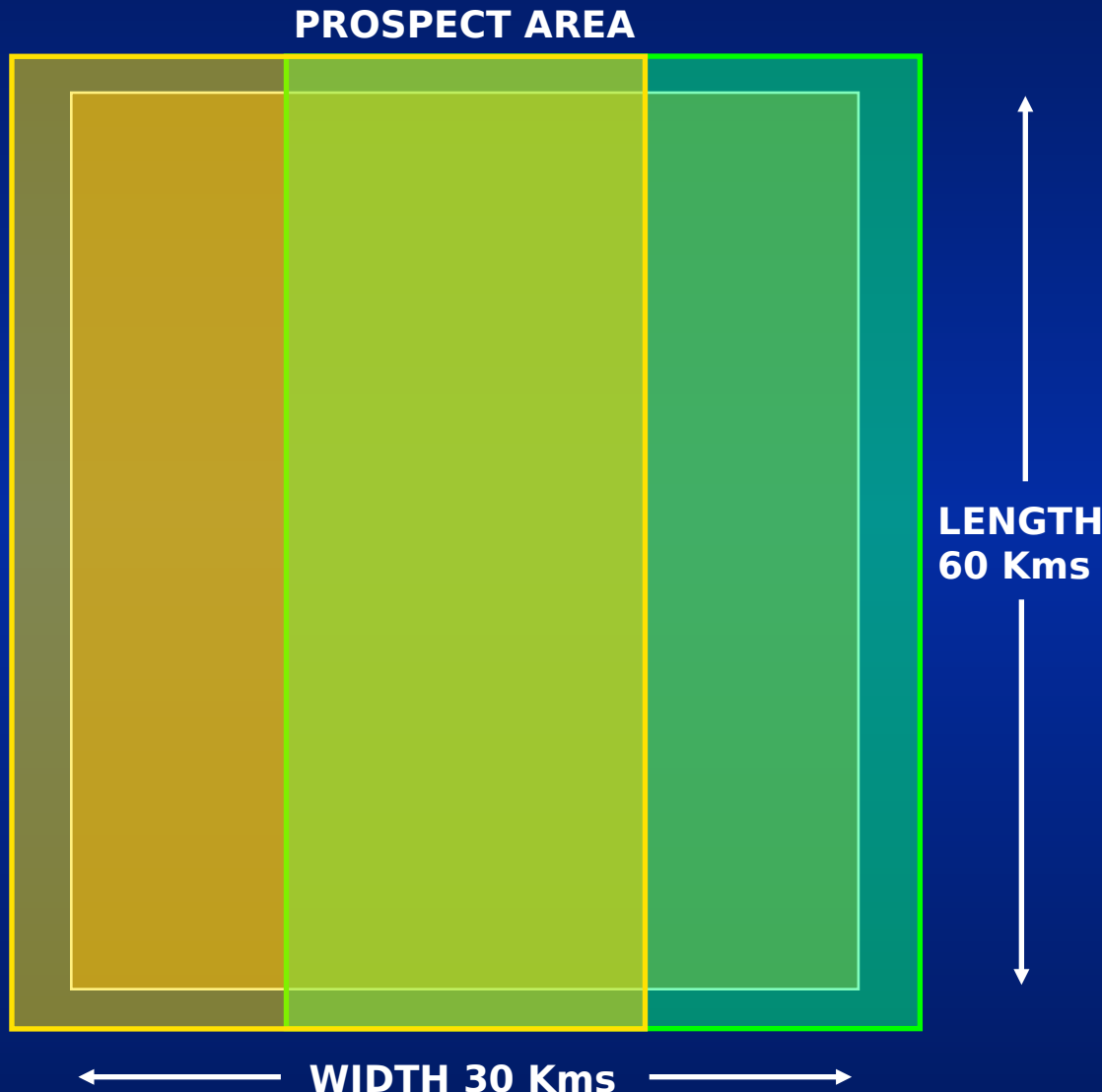
1 Sweep per VP

16 Second Sweep Time

6 Second Listen Time

Vibrators In Centre of Live Spread

Client Parameters - Prospect Area & Blocks



RECEIVER PARAMETERS

Each Receiver Line = $192 \times 50\text{m} = 9.60\text{Km}$ Long

The crew has 5760 Stations of Geophones
excluding Spare Strings to lay on 12+0.5 Lines

= 460 Stations per Receiver Line $\times 50\text{m}$

= 23.04 Kms of Geophones per Receiver Line

But the Prospect is 30Kms Wide, so it is
necessary to split the Prospect into 2 Blocks

Agenda

Introduction

Overall Process Flow

Crew Operations

- Acquisition Parameter Selection
- **Surveying Operations**
- Recording Operations
- Seismology Operations
- Logistics Support

Productivity

Finance

Some of the Differences Between Land/TZ and
Marine Acquisition

Conclusions

Surveying the Block

SURVEY PARAMETERS

Vibrator and Receiver Centre of Gravity Points are positioned.

All Points located to an accuracy of ± 3 metre against the Preplan then the Actual location is measured to an accuracy of ± 1 metre.

Typically there are 12 GPS Surveying Crews who average 300 Points per Day. They walk over 15 Kms across country daily.

Offset Points must be positioned when obstacles e.g. pipeline, roads prevent desired positioning.



Statistics slide

A typical Survey Section section for a large 3-D Desert crew with 22 receiver lines and 50 m Receiver & Source intervals would have :

- **3 Personnel Carriers**
- **3 Light vehicles**
- **10 GPS backpacks**
- **2 Base stations**
- **15 GPS operators**
- **12 Chainmen**
- **6 Peg/Stake men**
- **3 foremen**
- **8 surveyors**
- **2500 points surveyed / day (Source & Receiver)**

Agenda

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- **Recording Operations**
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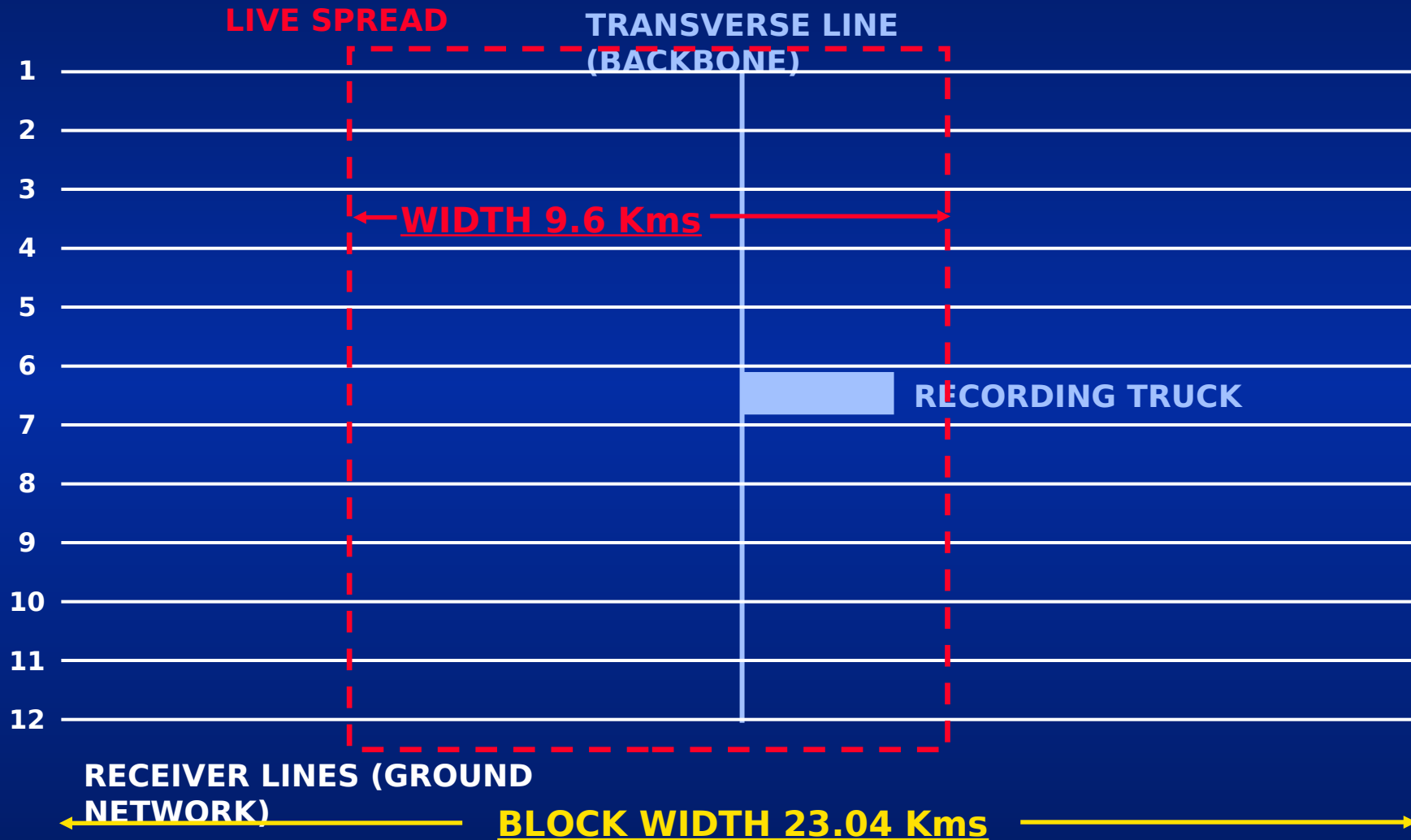
Productivity

Finance

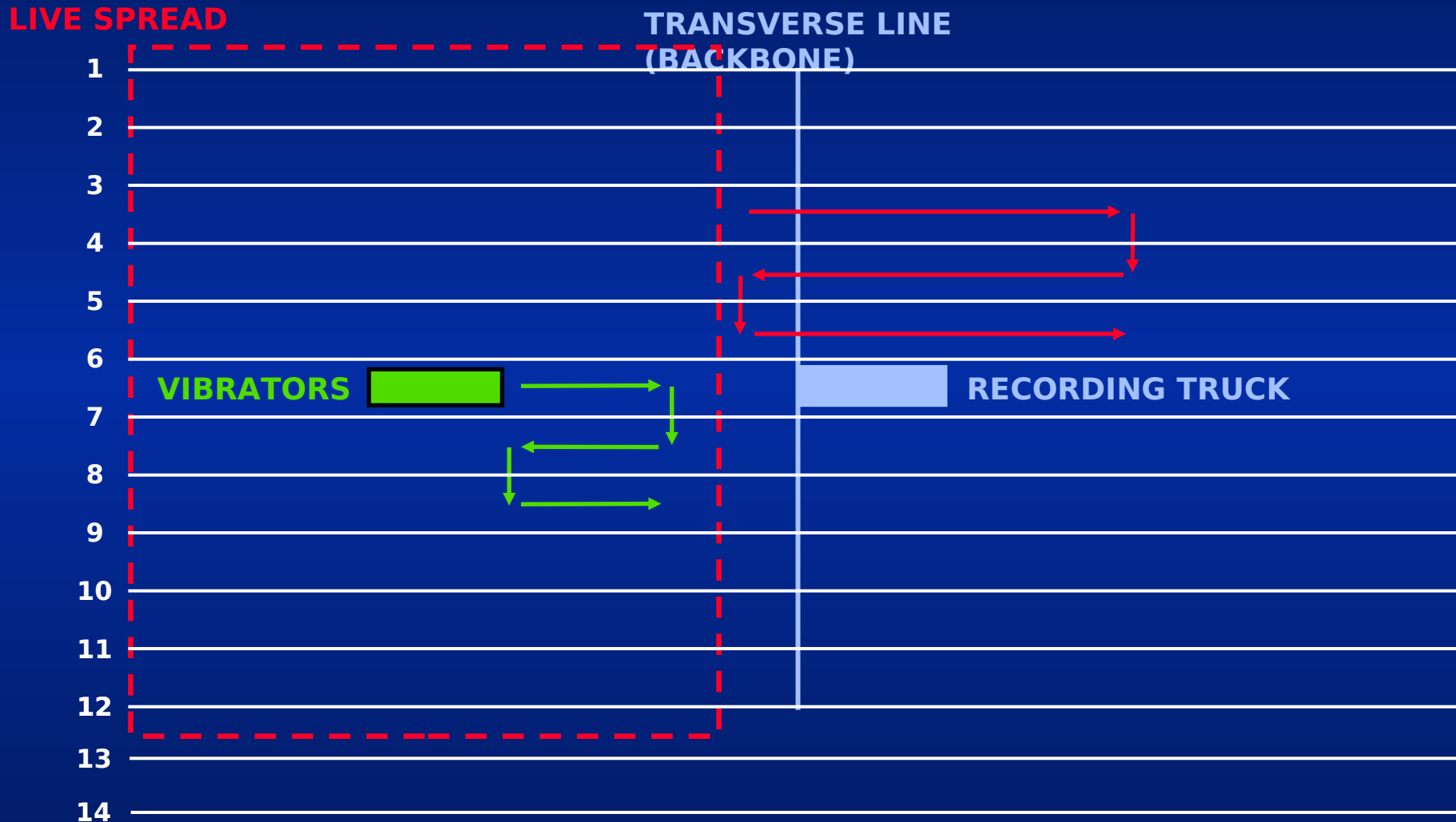
Some of the Differences Between Land/TZ and
Marine Acquisition

Conclusions

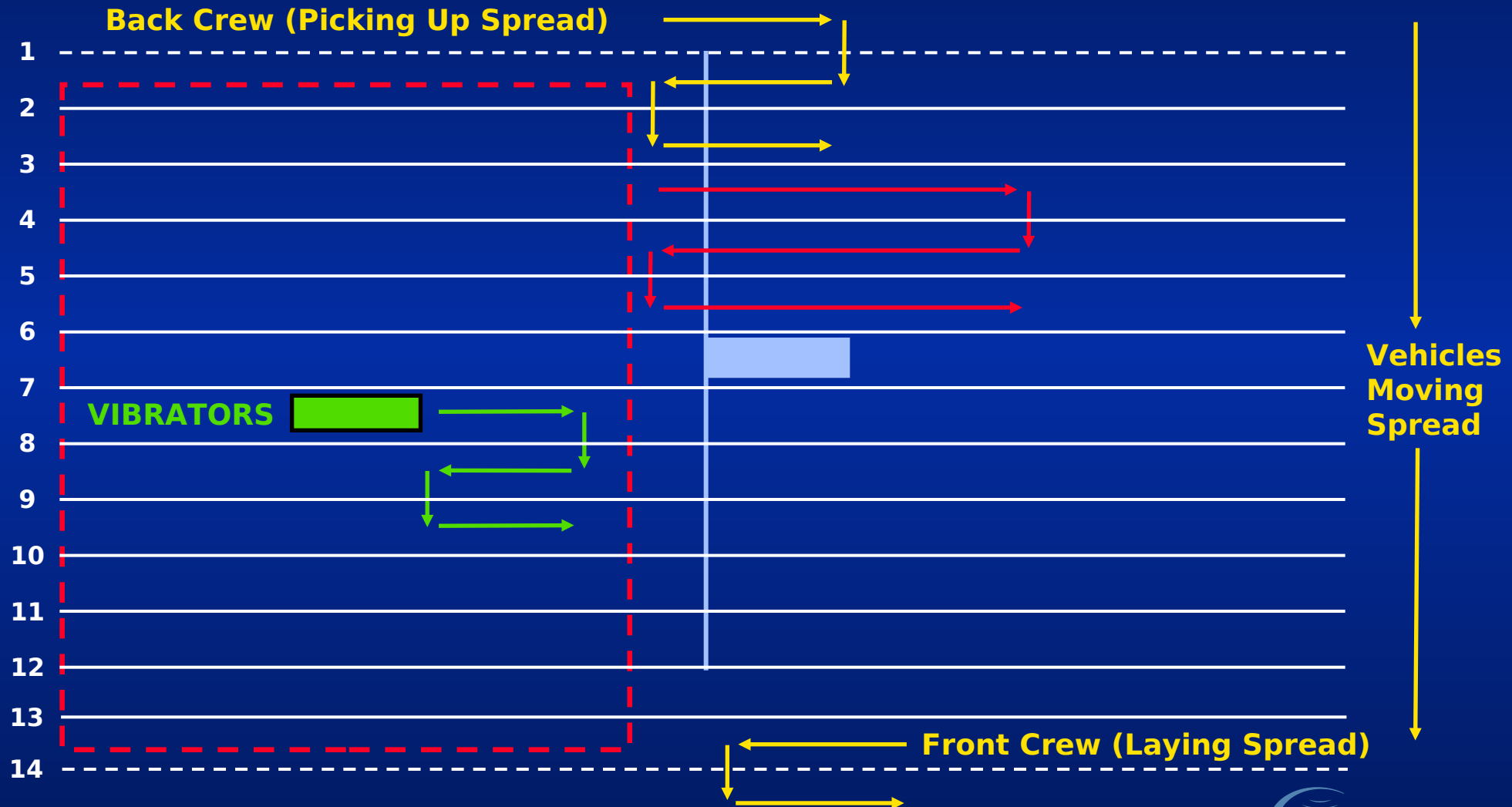
Receiver Spread in A Single Block



Movement of Vibrators & Live Spread



Movement of Receivers



Front Crew on a land Seismic Crew



DP START Oslo
2004



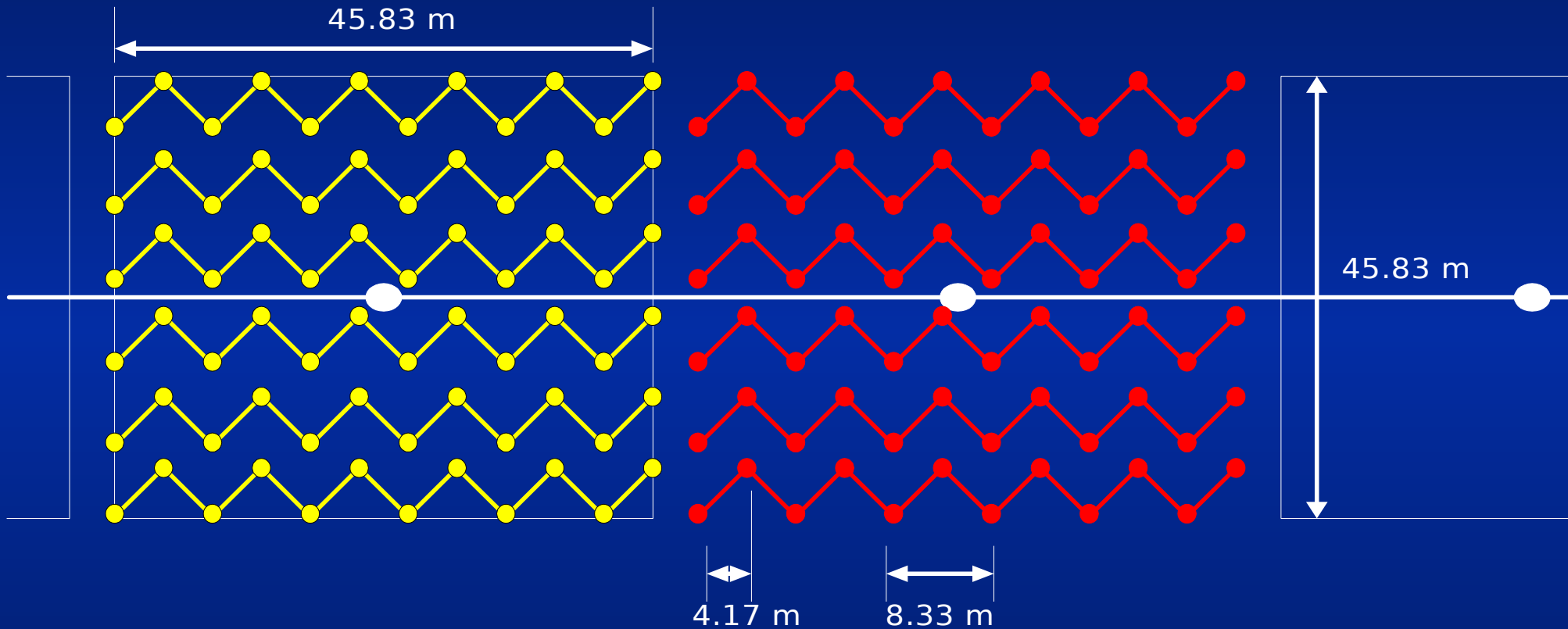
Desert Crews-Saudi-Layout



Desert Crews-Saudi-Pickup



Individual Geophone Stations



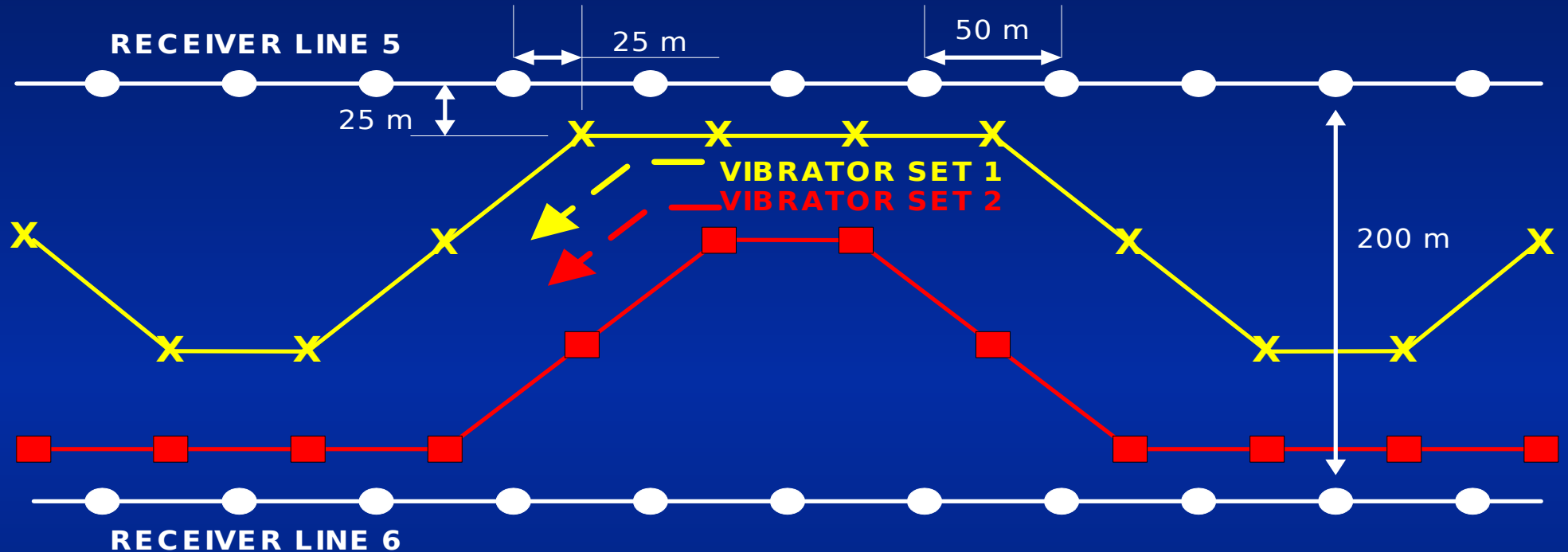
GEOPHONE STATION CENTRE OF GRAVITY



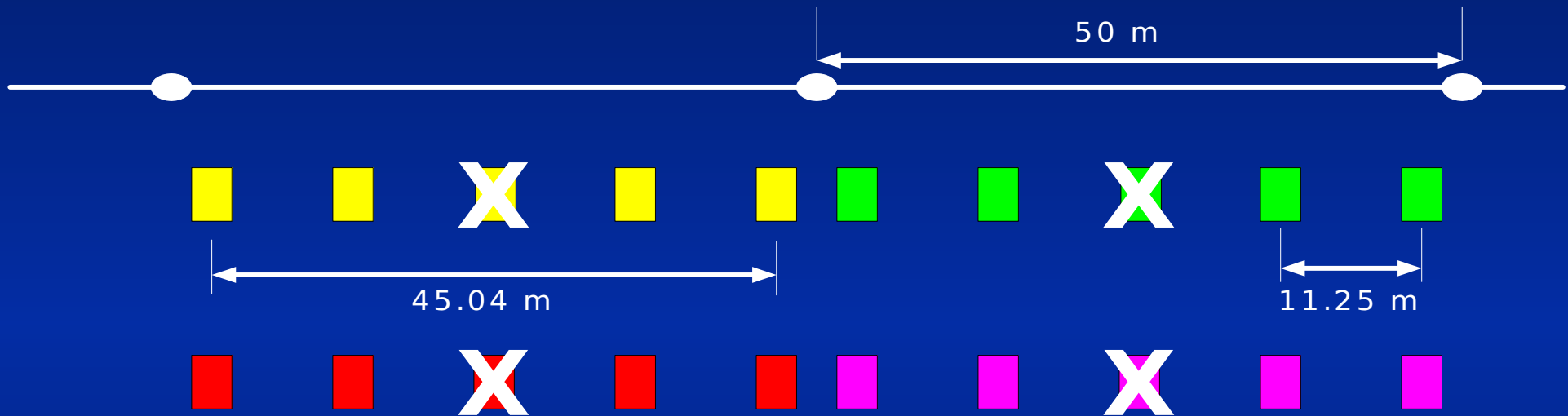
INDIVIDUAL GEOPHONES

DP START Oslo
2004

Movement of Vibrators



Vibrator Pattern (VP)



- X** VIBRATOR POINT CENTRE OF GRAVITY
- Yellow** **Green** VIBRATOR SET 1 PAD POSITIONS
- Red** **Magenta** VIBRATOR SET 2 PAD POSITIONS
- White Circle** RECEIVER STATION CENTRE OF GRAVITY

The Vibrators Moving (In Kuwait)

